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Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control. The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covered publications printed in 1968 and 1969, while the second annual issue lists publications printed in 1970 and 1971, the third annual issue covers calendar years 1972 and 1973, and the fourth and fifth annual issues cover literature published in 1974 and 1975. This annual issue lists publications printed in 1976. This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.
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SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS 1976

Sixth Annual Issue

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ADA, OKLAHOMA 74820

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C Galegar

William C. Galegar
Director
Robert S. Kerr Environmental
Research Laboratory

PREFACE

The sixth annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS has been compiled from approximately 100 sources of material covering calendar year 1976. This compilation has attempted to include technological and institutional articles that would be pertinent to action programs regarding the control of water quality degradation resulting from irrigated agriculture.

The state-of-the-art report, "Characteristics and Pollution Problems of Irrigation Return Flow" prepared by the Utah State University Foundation contains a bibliography of articles pertinent to Irrigation Return Flow Quality through 1967. The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS listed publications appearing in calendar years 1968 and 1969, while the second annual issue listed publications appearing in calendar years of 1970 and 1971, the third annual issue contained abstracts of articles and reports published during calendar years 1972 and 1973, and the fourth annual issue contains abstracts of 1974 publications, and the fifth annual issue contains abstracts of 1975 publications. The sixth annual issue contains 638 abstracts of documents published during calendar year 1976. The abstracts have been placed into sections according to the category and subgroup classifications used by the Water Resources Scientific Information Center (WRSIC) as published in the report, "Water Resources Thesaurus." The abstracts have been forwarded to WRSIC for inclusion in their bi-monthly publication, "Selected Water Resources Abstracts."

ABSTRACT

Research related to the quality of irrigation return flow is being conducted at numerous institutions throughout the western United States. Related work is also underway at other institutions in the United States, as well as other portions of the world. Approximately 100 sources of material have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. These articles describe water quality problems resulting from irrigated agriculture, potential technological solutions for controlling return flows, recent research pertinent to return flow investigations, and literature associated with institutional constraints in irrigation return flow quality control.

The first annual issue of SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS covered publications printed in 1968 and 1969, while the second annual issue lists publications printed in 1970 and 1971, the third annual issue covers calendar years 1972 and 1973, and the fourth and fifth annual issues cover literature published in 1974 and 1975. This annual issue lists publications printed in 1976. This report was submitted in fulfillment of Grant Number R-800426 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.

Key Words: Fertilizers, Irrigated Land, Irrigation Systems, Irrigation Water, Nitrates, Phosphates, Return Flow, Salinity, Water Pollution Effects, Water Pollution Sources, Water Quality Control.

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The scope of this literature abstracting effort has been delineated jointly by the senior author and the Project Officer, Mr. Alvin L. Wood, Source Management Branch, Robert S. Kerr Environmental Research Laboratory, Environmental Protection Agency, Ada, Oklahoma. The cooperative efforts of the Project Officer in meeting with project personnel and reviewing the abstracting process have been very helpful and are sincerely appreciated.

Section I

WATER CYCLE

GENERAL (GROUP 02A)

76:02A-001
HYDROLOGY OF THE NORTH CASCADES REGION, WASHINGTON: I. RUNOFF, PRECIPITATION, AND STORAGE CHARACTERISTICS,
Rasmussen, L.A., and Tangborn, W.V.
Geological Survey, Tacoma, Washington.
Water Resources Research, Vol. 12, No. 2, p 187-202, April 1976. 10 fig, 7 tab, 6 ref.

Descriptors: *Streamflow forecasting, *Hydrology, Hydrologic data, *Washington, Equations, Data collections, Evaluation, Methodology, Stream gages, Ice, Snow, Altitude, Topography, Physical properties.

The time and space distributions of measured precipitation and measured runoff and of spring storage, which is approximately equal to the subsequent summer runoff of snowmelt and stored groundwater, have been analyzed for the North Cascades region of Washington. Neither precipitation nor runoff shows a consistent relationship with altitude, chiefly because of precipitation-shadowing effects in this region of high relief. The relationship between mean annual precipitation and altitude is improved considerably when a topographic mean altitude is used instead of the actual altitude of the weather station. However, the improvement is not sufficient to explain a number of discrepancies that still occur. Some of the scatter in a precipitation-altitude plot appears to be due to a deficient precipitation catch by high-altitude gages. When the dependence of runoff on precipitation was examined on an annual, seasonal, and monthly basis, only a few low-altitude gages correlated well with basin runoff. In several instances, annual (water year) runoff could be better predicted from winter precipitation than from annual precipitation.

76:02A-002
HYDROLOGY OF THE NORTH CASCADES REGION, WASHINGTON: II. A PROPOSED HYDROMETEOROLOGICAL STREAMFLOW PREDICTION METHOD,
Tangborn, W.V., and Rasmussen, L.A.
Geological Survey, Tacoma, Washington.
Water Resources Research Vol. 12, No. 2, p 203-216, April 1976. 4 fig, 8 tab, 19 ref.

Descriptors: *Streamflow forecasting, *Model studies, *Hydrology, *Meteorology, *Washington, Methodology, Hydrologic data, Regression analysis, Hydrologic cycle, Snow, Ice, Rainfall.

On the basis of a linear relationship between winter (October-April) precipitation and annual runoff from a drainage basin (Rasmussen and Tangborn, 1976) a physically reasonable model for predicting summer (May-September) streamflow from drainages in the North Cascades region in Washington was developed. This hydrometeorological prediction method relates streamflow for a season beginning on the day of prediction to the storage (including snow, ice, soil moisture , and groundwater) on that day. The spring storage is inferred from an input-output relationship based on the principle of conservation of mass: spring storage equals winter precipitation to the basin less winter runoff from the basin and less winter evapotranspiration. The method of prediction is based on data only from the years previous to the one for which the prediction is made, and the system is revised each year as data for the previous year become available. Standard precipitation and runoff measurements in the North Cascades region are adequate for constructing a predictive hydrologic model. This model can be used to make streamflow predictions that compare favorably with current multiple regression methods based on mountain snow surveys. This method has the added advantages of predicting the space and time distributions of storage and summer runoff.

76:02A-003
EVALUATION OF A MONTHLY WATER YIELD MODEL,
Haan, C.T.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 55-60, January-February 1976. 6 fig, 3 tab, 11 ref.

Descriptors: *Model studies, *Watersheds, (Basins), *Runoff, Mathematical models, Precipitation (Atmospheric), Rainfall, Evapotranspiration, Seepage, Soil water, Streamflow, Hydrographs, Hydrology, *Water yield.

The results of evaluating the performance of a monthly water yield model on 46 watersheds located in Kentucky, North Carolina, South Carolina, Tennessee, and Virginia were reported. In general, whenever the watershed being modeled met the assumptions under which the model was developed, the model performance was satisfactory. The assumptions included: (1) no runoff due to snow, (2) daily rainfall evenly distributed over the entire watershed, (3) short delays between rainfall and runoff, (4) stationary response characteristics between rainfall and runoff, and (5) record available for parameter estimation is representative of watershed behavior.

76:02A-004
DISAGGREGATION MODELS IN HYDROLOGY REVISITED,
Mejia, J.M, and Rousselle, J.
Ecole Polytechnique de Montreal, Quebec, Canada.
Water Resources Research, Vol. 12, No. 2, p 185-186, April 1976. 5 ref.

Descriptors: *Synthetic hydrology, *Time series analysis, *Statistical models, Hydrology, Analytical techniques, Correlation analysis, Seasonal, Hydrologic data, Flow, *Model studies.

The synthesis of hydrologic sequences has been advanced as a useful tool in water resource systems. Valencia and Schaake developed a methodology for the disaggregation of synthesized yearly flow sequences in such a way that the statistics at different time resolutions were preserved. Though the data inside a given year preserve the statistics for all levels of aggregation, they are linked with the past only through the statistics at the yearly level. To overcome this shortcoming, a modification in the methodology was proposed and tested on 24 years of hydrologic information for two stations located in the watershed of the North River. The results supported the theory behind the modified model.

76:02A-005
PARAMETER OPTIMIZATION FOR WATERSHED MODELS,
Johnston, P.R., and Pilgrim, D.H.
New South Wales University, School of Civil Engineering, Kensington, Australia.
Water Resources Research, Vol. 12, No. 3, p 477-486, June 1976. 13 fig, 16 ref.

Descriptors: *Watersheds (Basins), *Mathematical models, *Parametric hydrology, *Optimization, Numerical analysis, Performance, Value, Soil moisture, Drainage, Systems analysis, Model studies.

A detailed search for the optimum values of the parameters of the Boughton model is described. The Simplex and Davidon optimization methods were used. Rapid initial reductions in the objective function were readily achieved, but the solutions approached several widely different apparent optima. Alternate use of different optimization methods and numerical and asgebraic studies enabled considerable further progress to be made in the search. Much information was obtained on various aspects of parameter optimization. These include interdependence and indifference of parameters, the form of the response surface and the occurrence of discontinuities, the required length of the "warm-up" period for different types of stores, and the effects of using different types of objective functions. As typical stores were analyzed and the only basic assumption involved was that the data contained errors, the findings should apply to most watershed models.

76:02A-006
MULTISTATION, MULTIYEAR SYNTHESIS OF HYDROLOGIC TIME SERIES BY DISAGGREGATION,
Tao, P.C., and Delleur, J.W.
Purdue University, School of Civil Engineering, Lafayette, Indiana.
Water Resources Research, Vol. 12, No. 6, p 1303-1312, December 1976. 5 fig, 3 tab, 19 ref. OWRT B-036-IND(15).

Descriptors: *Rainfall, *Ohio River, *Mississippi River, *Runoff, *Model studies, Mathematical models, Time series analysis, Rainfall-runoff relationships, Streams, Graphical analysis, Tributaries, Basins, Correlation analysis, Watersheds (Basins), Hydrology.

A model was presented which is designed for multivariate (multistation, multiyear) data syntheses, such as the simulation of several rainfall series over a region, of tributaries and mainstream runoff series, and of rainfall and concurrent runoff series in watersheds. The model was an application of the disaggregation scheme proposed by Valencia and Schaake. If a time series of higher-level (e.g., annual) events for each station has been generated by some scheme which preserves the long-term properties, then the disaggregation model can be used to generate parallel time series of lower-level (e.g., monthly, weekly) events for each corresponding station. The aggregation of the generated lower-level sequences can preserve the long-term properties of the original higher-level series. The seasonal variations, the means, the variances, the autocovariances, and the cross-covariances, properties of the original lower-level time series, are also conserved. The lower-level generated series also preserves the correlations between stations. The generation of multivariate normal random numbers makes use of either the Crout factorization or the principal component analysis, depending on whether the covariance matrix of the lower-level series is positive definite or positive semidefinite, respectively. A technique for modeling nonnormal resudual components was discussed. The model was applied to 36 rainfall runoff, and rainfall-runoff sequences in the lower Ohio and upper Mississippi River basins located in Indiana, Illinois, Ohio, and Kentucky. The properties of the generated data series show excellent agreement with those of the historical observed data series.

76:02A-007
AN ANALYSIS OF THE EFFECTS OF PARAMETER UNCERTAINTY IN DETERMINISTIC HYDROLOGIC MODELS,
Wood, E.F.
International Institute for Applied Systems Analysis, Laxenburg, Austria.
Water Resources Research, Vol. 12, No. 5, p 925-932, October 1976. 12 fig, 1 tab, 6 ref.

Descriptors: *Parametric hydrology, *Model studies, Analytical techniques, *Flood frequency, *Simulation analysis, *Rainfall-runoff relationships, Stochastic processes, Water resources, Water loss, Systems analysis, Equations, Risks.

The uncertainty in the output of deterministic models, due to the uncertainty in the parameters of the model, is analyzed and compared to current procedures of using average values for the uncertain parameters. The present analysis considers an analytical rainfall-runoff flood frequency model where the infiltration parameter is considered as a stochastic variable. The same conceptual procedure can be used to analyze fixed but uncertain (unknown) parameters. The extension to analyzing parameter uncertainty in large simulation models is indicated, and the importance of such analyses is discussed.

76:02A-008
A DISTRIBUTED CONVERGING OVERLAND FLOW MODEL: II. EFFECT OF INFILTRATION,
Sherman, B., and Singh, V.P.
New Mexico Institute of Mining and Technology, Socorro, New Mexico.
Water Resources Research, Vol. 12, No. 5, p 897-901, October 1976. 4 fig, 15 ref, 1 append.

Descriptors: *Model studies, *Infiltration, *Overland flow, Distribution systems, Hydrologic systems, Mathematical models, Agricultural watersheds, Runoff, Rainfall, Rainfall-runoff relationships, Hydrology, Equations.

The overland flow on an infiltrating converging surface was studied. Mathematical solutions were developed to study the effect of infiltration on nonlinear overland flow dynamics. To develop mathematical solutions, infiltration and rainfall were represented by simple time and space invariant functions. For complex rainfall and infiltration functions, explicit solutions were not feasible.

Section II

WATER CYCLE

PRECIPITATION (GROUP 02B)

76:02B-001
EVALUATION OF MEAN SQUARE ERROR INVOLVED IN APPROXIMATING THE AREAL AVERAGE OF A RAINFALL EVENT BY A DISCRETE SUMMATION,
Bras, R.L., and Rodriguez-Iturbe, I.
Puerto Rico University, Department of Civil Engineering, Mayaquez, Puerto Rico.
Water Resources Research, Vol. 12, No. 2, p 181-184, April 1976. 3 fig, 8 ref.
NWS 4-36738.

Descriptors: *Rainfall, *Data processing, *Networks, Mathematics, Mathematical studies, Analytical techniques, Average, Correlation analysis, Precipitation (Atmospheric), Hydrology.

Two-dimensional areal processes are commonly evaluated in hydrology through a discretization in space over the region in which the process is being studied. Such a discretization involves an error in going from the continuous process to the discrete one. This error was studied theoretically, and graphs were presented for its evaluation as function of the size of the area, the functional form of the correlation equation in space,and the level of discretization or size of the sample. Correlation structures of the Bessel type and of the single and double exponential kind were considered, and their different implications were discussed.

76:02B-002
FINE-SCALE TIME VARIATIONS OF RAINFALL IN WESTERN OREGON,
Trump, C.L., and Elliott, W.P.
Oregon State University, School of Oceanography, Corvallis, Oregon.
Water Resources Research, Vol. 12, No. 3, p 556,560, June 1976. 3 fig, 3 tab, 11 ref.

Descriptors: *Rainfall, *Oregon, *Illinois, *Pacific Ocean, Winter, Linear programming, Statistics, Storms, Mathematical studies, Precipitation (Atmospheric), Time series analysis, On-site investigations, Variability, Seasonal, On-site data collections.

One-minute rain rates were measured at three stations on a line running inland from the coast across a low mountain range during a winter rainy season. The average of three nondimensional variability statistics were significantly greater on the coast than inland. Rain rate distributions showed that a greater portion of the rain fell at higher rates on the coast, and autocorrelation analysis showed that the rainfall was less persistent on the coast than inland. Oregon results were compared with similar results concerning Illinois summer convective rainfall. Even though the Illinois rainfall was distinctly more intense and less persistent than the Oregon rainfall, the relative variabilities were surprisingly similar. The logarithm of the total rain falling at rates greater than a given rate was found to be a linear function of that rate. It was found that the concentrations of large airborne sea-salt particles, the cloud-forming nuclei, peaked at the coastline and dropped off rapidly inland.

76:02B-003
RAINFALL GENERATION: A NONSTATIONARY TIME-VARYING MULTIDIMENSIONAL MODEL,
Bras, R.L., and Rodriguez-Iturbe, I.
Puerto Rico University, Department of Civil Engineering, Mayaquez, Puerto Rico.
Water Resources Research, Vol. 12, No. 3, p 450-456, June 1976. 3 fig, 2 tab, 24 ref. NWS Contract 4-36738.

Descriptors: *Rainfall, *Model studies, *Storms, Algorithms, Statistics, Water resources, Precipitation (Atmospheric), Rainfall intensity, Areal, Hyetographs, Equations.

Most existing rainfall models do not concentrate on storm exterior characteristics. Very few models attempt to generate exterior and interior rainfall characteristics everywhere in space, and those that do have limiting assumptions of stationary behavior at all levels of storm activity. Therefore, a nonstationary, multidimensional model was suggested. The suggested model, capable of simulating historical storm exteriors and interiors, assumed the validity of G.I. Taylor's hypothesis turbulence within the storm interior. First-order statistics of storm interiors as well as the correlation in time and space of the storm interiors were preserved. The model had the advantages of being based on concepts easy to understand, being multi-dimensional, and being computationally easy to implement. The research described would be applicable for any kind of rational description of the rainfall process.

76:02B-004
NETWORK DESIGN FOR THE ESTIMATION OF AREAL MEAN OF RAINFALL EVENTS,
Bras, R.L., Rodriguez-Iturbe, I.
Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, Massachusetts.
Water Resources Research, Vol. 12, No. 6, p 1185-1195, December 1976. 11 fig, 6 tab, 17 ref. OWRT C-4118 (No. 9021)(14).

Descriptors: *Design, *Rainfall, *Networks, *Estimating, *Optimization, Areal, Precipitation, Methodology, Sampling, Costs, Stochastic processes, Hydrology, Equations, Computers, Algorithms, Linear programming, Decision making, Systems analysis, Mathematical models.

Presented is an efficient network design procedure which is feasible technically and economically. The procedure combines accuracy (accounting for the process and instrument uncertainties) and cost considerations in a way flexible enough to include characteristics and constraints particular to the problem at hand and to the interested designer. This work recognizes rainfall as a multidimensional stochastic process. By using the knowledge of such processing and of multivariate estimation theory, the procedure (optimization) for designing an accurate, least-cost network to obtain the areal mean precipitation of an event over a fixed area is developed. Data collection is viewed as an estimation problem. The methodology allows consideration of the following aspects of network design: (1) spatial uncertainty and correlation of process; (2) errors in measurement techniques and their correlation; and (3) nonhomogenous sampling costs. Optimal networks are given in terms of the number of location of stations together with the resulting cost and mean square error of rainfall estimation.

76:02B-005
RAINFALL NETWORK DESIGN FOR RUNOFF PREDICTION,
Bras, R.L., and Rodriguez-Iturbe, I.
Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, Massachusetts.
Water Resources Research, Vol. 12, No. 6, p 1197-1208, December 1976. 5 fig, 3 tab, 17 ref.

Descriptors: *Rainfall, *Stochastic processes, *Networks, *Runoff forecasting, Equations, Runoff, Kinetics, Basins, Rainfall-runoff relationships, Flood forecasting, Discharge (Water), Model studies.

A multivariate, state space stochastic model of rainfall based on a multi-dimensional rainfall generator suggested by Bras and Rodriguez-Iturbe was used, together with a runoff model, to study the accuracy of discharge prediction as a function of the rainfall-sampling network. The runoff model used was a spatially distributed simulation based on a finite difference solution of the kinematic wave equations. Discharge prediction accuracy at any point in a basin could be obtained in terms of the mean square error as a function of the number of rain-sampling devices. The solution was also a function of the physics of the basin at hand, which was incorporated in the rainfall-runoff model. The mean square error of discharge estimation was obtained by using linear estimation theory for dynamic systems. Particularly, the technique used was the Kalman-Buch filter, which permitted filtering and extrapolation of noisy and incomplete observations.

76:02B-006
COMPUTATION OF SOLAR RADIATION FROM SKY COVER,
Thompson, E.S.
National Weather Service, Office of Hydrology, Silver Spring, Maryland.
Water Resources Research, Vol. 12, No. 5, p 859-865, October 1976. 5 fig,
2 tab, 6 ref, 1 append.

Descriptors: *Cloud cover, *Solar radiation, *Model studies, *Equations, Mathematical models, Analytical techniques, Data processing, Correlation analysis, Radiation, Energy transfer, Atmosphere, Meteorology.

A procedure for estimating global solar radiation from sky cover was developed from the records of 47 stations in the United States, with long periods of radiation observations during the 10-year period, March 1961 through February 1971. The procedure fits a general parabolic equation of the form Y = B + (1-B) (1-N to the P power) to the observations, where Y is the observed global solar radiation divided by clear sky radiation and N is the sky cover. The variables B (the point at which the parabola crosses the y axis) and P (a variable parameter less than 1.0) were selected to minimize the sum of the errors (Y - Y sub calc squared), where Y sub calc is the calculated value of Y. The equation Y = B + (1 - B)(1 - N to the 0.61 power) was selected as most representative, and the B values in this equation that minimize the sum of the errors squared for the individual stations were shown. The average absolute error of the 5,306 data points is 1.18 MJ/sq m, or 7% of the average observed radiation. Because of the uncertainties of the observed global solar radiation and observed sky cover, the procedure should be used with caution, particularly for periods of less than 1 month.

76:02B-007
A MARKOV CHAIN MODEL OF DAILY RAINFALL,
Haan, C.T., Allen, D.M., and Street, J.O.
Kentucky University, Department of Statistics, Lexington, Kentucky 40506
Water Resources Research, Vol. 12, No. 3, p 443-449, June 1976. 10 tab, 8 ref.

Descriptors: Rainfall, Rainfall disposition, Model studies, Simulation analysis, Precipitation, Rainfall simulators.

The design of many water resources projects requires knowledge of possible long-term rainfall patterns. A stochastic model based on a first-order Markov chain was developed to simulate daily rainfall at a point. The model uses historical rainfall data to estimate the Markov transitional probabilities. A separate matrix is estimated for each month of the year. In this research, 7 times 7 transitional probability matrices were used. The model is capable of simulating a daily rainfall record of any length, based on the estimated transitional probabilities and frequency distributions of rainfall amounts. The simulated data have statistical properties similar to those of historical data.

76:02B-008
UNIFORMITY AMONG WEATHER MODIFICATION LAWS,
Davis, R.J.
Arizona University, Department of Law, Tucson, Arizona
Journal of the Irrigation and Drainage Division, Volume 102, No. IR3, p 285-294,
September 1976. 1 tab, 11 ref.

Descriptors: Weather modification, Cloud seeding, Precipitation, Rainfall.

Advocates of weather modification would do well to consider the advantages of uniformity and of diversity in laws relating to cloud seeding. They should support state legislation that promotes uniformity where it is useful and retains diversity where it is rational to do so. When additional federal legislation is considered, the weather modification community should press for provisions that permit retention of diversity among states where it is advantageous. Neither Procrustes nor Balkanization should prevail.

Section III

WATER CYCLE

SNOW, ICE, AND FROST (GROUP 02C)

76:02C-001
AN ANALYSIS OF WATER FLOW IN DRY SNOW,
Colbeck, S.C.
Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.
Water Resources Research, Vol. 12, No. 3, p 523-527, June 1976. 3 fig, 1 tab,
12 ref. Army 4A161102B52E.

Descriptors: *Water supply, *Snow, Water, Advection, Water measurement, Runoff, Wetting, Temperature, Adsorption, Flow rates, Thermodynamic behavior, Flow, Grain size, Time lag, Discharge (Water), Equations.

Equations describing water movement in a dry snow cover were derived, and examples of flow through ripe, refrozen, and fresh snows were given. As the leading edge of a wave of liquid water advanced into subfreezing snow, the liquid water was the principal source of the thermal energy needed to raise the snow to its melting temperature, because advection of water is generally faster than heat conduction. There are three requirements which have to be met before the wetting front can propagate past any level. First, a volume of water per unit volume of snow has to be frozen onto the snow grains in order to supply enough latent heat to raise the snow to O.C. Second, a volume of water per unit volume of snow has to be supplied to fill the residual water requirement, retained as an adsorbed film, and the water held immobile in the menisci between the snow grains. Third, any additional water supplied is mobile, and in principle the wetting front propagates downward at a rate determined by the rate at which water can be supplied to raise the liquid saturation to the level which corresponds to the value of water flux just above the wetting front. These requirements delay and reduce runoff following rain on dry snow.

Section IV

WATER CYCLE

EVAPORATION AND TRANSPIRATION (GROUP 02D)

76:02D-001
RELATIVE IMPORTANCE OF SOIL RESISTANCE AND PLANT RESISTANCE IN ROOT WATER ABSORPTION,
Reicosky, D.C., and Ritchie, J.T.
Agricultural Research Service, Florence, South Carolina, Southern Region.
Soil Science Society of America Journal, Vol. 40, No. 2, p 293-297, March-April 1976. 3 fig, 1 tab, 32 ref.

Descriptors: *Soil-water-plant relationships, *Moisture uptake, *Soil water, *Transpiration, Water loss, Leaves, Corn, Sorghum, Nutrients, Root zone, Absorption, Sands, Soil types, Clays, Hydraulic conductivity.

The relative importance of soil and plant resistances and their influence on leaf water potential and transpiration over a range of measured hydraulic conductivities and matric potentials commonly encountered in Varina sandy loam and Houston Black Clay was evaluated. Experiments were conducted on corn grown in a greenhouse and sorghum grown in a field. Soil water potentials, leaf water potentials, and transpiration rates were determined to evaluate the magnitude of the combined soil and plant resistances to water flow in the plant system. Results show that when root density was not unusually low, plant resistance to water transport was much larger than soil resistance until a higher threshold soil hydraulic conductivity was reached. These findings emphasize the need to consider plant resistance in moisture uptake calculations when using equations that evaluate water potential gradients along the water flow path.

76:02D-002
EVAPOTRANSPIRATION MODEL TESTED FOR SOYBEAN AND SORGHUM,
Kanemasu, E.T., Stone, L.R., and Powers, W.L.
Kansas State University, Department of Agronomy, Manhattan, Kansas.
Agronomy Journal, Vol. 68, No. 4, p 569-572, July-August 1976. 3 fig, 3 tab, 13 ref. OWRT A-056-KAN(3).

Descriptors: *Evapotranspiration, *Sorghum, *Soybeans, *Model studies, Evaporation, Transpiration, Advection, Stomata, Lysimeters, Temperature, Soil moisture, Soil water movement, Solar radiation.

Daily evapotranspiration estimated using a new model applied to sorghum and soybeans was within 2 mm of estimates by lysimetric observation. The model employs daily inputs of temperature, solar radiation and leaf area index; outputs include transpiration and evaporation. The model has potential in scheduling irrigation on a routine basis. Seasonal evaporation accounted for 15 to 20% of the evapotranspiration which was about 10% greater from soybeans than from sorghum. Nightime evapotranspiration losses (lysimetric) from soybeans were also 1.8 times greater, indicating lower stomatal resistance. Leaf area indices indicated a greater surface resistance for sorghum.

76:02D-003
AN EVAPORATION EQUATION FOR AN OPEN BODY OF WATER EXPOSED TO THE ATMOSPHERE,
Goodling, J.S., Sill, B.L., and McCabe, W.J.
Auburn University, Department of Mechanical Engineering, Alabama.
Water Resources Bulletin, Vol. 12, No. 4, p 843-853, August 1976. 3 fig, 10 ref.

Descriptors: *Evaporation, *Forced drying, *Wind velocity, Temperature, Air, Heat flow, Winds, Mass transfer, Equations, Air temperature, Numerical analysis, Mathematical studies.

Evaporation was identified as having two additive components: natural evaporation in the absence of wind, and forced evaporation in the presence of wind.

An evaporation equation was obtained for an open body of water exposed at the atmosphere by conversion of standard, horizontal flat plate heat transfer relationships to a mass transfer or evaporation equation, based on an average air temperature of 68F. A comparison of numerical values predicted by this equation was made with evaporation equations deduced from field measurements, and the agreement was favorable. The major differences between this equation and those previously developed were; (1) This equation was derived strictly from standard heat transfer expressions, and (2) A dependency of average fetch and air temperature (through transport properties) was shown. This approach established the correct dependencies of the field parameters so that future experimental measurements would have a sound theoretical basis.

76:02D-004
MODEL FOR PREDICTING EVAPOTRANSPIRATION FROM NATIVE RANGELANDS IN THE NORTHERN GREAT PLAINS,
Hanson, C.L.
Agricultural Research Service, Northwest Watershed Research Center, Boise, Idaho.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 471-481, May-June 1976. 5 fig, 4 tab, 42 ref.

Descriptors: *Evapotranspiration, *Range grasses, *Vegetation, *Model studies, *Great Plains, Water, Energy budget, Soil water, Ranges, Forecasting, Estimating, Mathematical models, On-site data collections.

A study was made to develop a model for estimating evapotranspiration from Northern Great Plains native rangeland, based on potential evapotranspiration, available soil water, leaf area, and direct evaporation from the soil and intercepted water from plants. To calibrate and test the model, data from Gillette, Wyoming, Cottonwood, South Dakota, and Sidney, Montana, were collected and evaluated. An optimization routine was employed to obtain the parameter values of the model. To estimate potential evapotranspiration, an approximate energy balance method and the United States Weather Bureau Class A pan evaporation were used because the data required by them were available or easily computed. The approximate energy balance method required daily solar radiation and mean daily air temperature. Based on model verification, the energy balance equation and the pan evaporation equation could be used to predict daily as well as mean 5-, 7-, and 10-day potential evapotranspiration. Model evaluation also indicated that it was better to use the approximate energy balance method than the Class A pan method for potential evapotranspiration. The model predicted daily as well as mean evapotranspiration better in loam soil areas than in fine clay soil areas.

76:02D-005
CALCULATION OF EVAPORATION RATES DURING THE TRANSITION FROM ENERGY-LIMITING TO SOIL-LIMITING PHASES USING ALBEDO DATA,
Jackson, R.D., Idso, S.B., and Reginato, R.J.
Agricultural Research Service, Water Conservation Lab, Phoenix, Arizona.
Water Resources Research, Vol. 12, No. 1, p 23-26, February 1976. 5 fig, 20 ref.

Descriptors: *Evaporation, *Energy transfer, *Soils, Albedo, Soil surfaces, Potential flow, Lysimeters.

A method was presented that utilizes albedo measurements to partition the fraction of the soil surface area exhibiting energy-limiting (potential) evaporation and the fraction exhibiting soil-limiting evaporation to calculate actual evaporation rates during the transition phase (energy limiting to soil limiting). Since albedo is proportional to the surface water content, the change in albedo from day to day was indicative of the fraction of the soil surface that was dry and evaporating at the soil-limiting rate. By denoting the partitioning factor as beta and by using a square root of time relation with a coefficient C for the soil-limiting phase the evaporation rate Ec for a day n after the soil was wet was expressed by a formula where Ep was the energy-limiting rate. The Priestly-Taylor formula was used to calculate Ep. Calculated evaporation rates were compared with lysimetrically determined rates. It was concluded that this method is reliable for calculating evaporation rates during the transition pnase of soil drying.

76:02D-006
RELATION OF THE CONSUMPTIVE USE COEFFICIENT TO THE DESCRIPTION OF VEGETATION,
Culler, R.C., Hanson, R.L., and Jones, J.E.
Geological Survey, Tucson, Arizona.
Water Resources Research, Vol. 12, No. 1, p 40-46, February 1976. 6 fig, 1 tab,
21 ref.

Descriptors: *Evapotranspiration, *Hydrologic budget, *Arid climates, *Arizona, Flood plains, Correlation analysis, *Vegetation, *Consumptive use, Transpiration, Analytical techniques, Aerial photography, Remote sensing, Equations.

Evapotranspiration from three reaches of the Gila River flood plain in Arizona was measured by the water budget during 1963-1971. Initially, the vegetation consisted of salt cedar and mesquite with densities of canopy ranging from 10 to 100%. The phreatophytes were removed in stages during 1967-1971. Perennial grass seed was applied but did not become established, and the postclearing vegetation was primarily annuals. Comparison of the evapotranspiration data from various reaches and comparison of data from before and after clearing required the application of an empirical equation. A consumptive use coefficient related to the description of vegetation was applied to an existing potential evapotranspiration equation based on macroclimatic observations. Initially, the vegetation description consisted of plant identification and canopy dimensions obtained by use of black and white aerial photography and ground measurements. In 1967, remote sensing in the form of color infrared aerial photography became available and densitometric interpretation was used to develop a spectral signature as the vegetation descriptor.

76:02D-007
RESISTANCE-ENERGY BALANCE METHOD FOR PREDICTING EVAPOTRANSPIRATION: DETERMINATION OF BOUNDARY LAYER RESISTANCE AND EVALUATION OF ERROR EFFECTS,
Verma, S.B., Rosenberg, N.J., Blad, B.L., and Baradas, M.W.
Kansas Water Resources Research Institute, Manhattan, Kansas.
Contribution No. 172, December 1975, p.I-1 thru I-29.

Descriptors: *Evapotranspiration, *Model studies, Measurement, *Sorghum, *Millet, *Advection, Lysimeters, Energy balance, Micrometerology, Microclimates, Heat transfer, Latent heat, Crop response.

A resistance model of evapotranspiration (ET) requiring measurement of boundary layer resistance, crop and air temperature, net radiation and soil heat flux was tested over sorghum and millet grown at Mead and Mitchell, Nebraska. Boundary layer resistance was estimated from friction velocity measurements used in a stability-corrected aerodynamic method. Friction velocity was computed by means of the Deacon-Swinbank approach. Evapotranspiration rates estimated by the resistance model compared well with results of lysimetric and energy balance measurements, on both a short-period and a daily basis. An error analysis was made to evaluate the relative influence of errors in measurement of the constituent input parameters. This analysis, in conjunction with field measurement, indicates that the resistance model evapotranspiration estimates are quite sensitive to errors in crop temperature measurement, especially in non-advective conditions, but are less strongly affected by errors in the estimation of boundary layer resistance. Boundary layer resistance for the sorghum and millet crops at varying stages of growth are presented as functions of windspeed.

76:02D-008
AN EVALUATION OF A RESISTANCE FORM OF THE ENERGY BALANCE TO ESTIMATE EVAPOTRANSPIRATION,
Heilman, J.L., and Kanemasu, E.T.
Kansas Water Resources Research Institute, Manhattan, Kansas.
Contribution No. 172, December 1975, p II-1 thru II-22.

Descriptors: *Evapotranspiration, *Model studies, Boundary layers, Heat resistance, Latent heat, Heat transfer, Lysimeters, Sorghum, Soybeans, Crop response.

An evapotranspiration model that uses the diffusion resistance to heat transport (rH) in the turbulent boundary layer was evaluated for soybean (Glycine max (L.) cv. Williams) and sorghum (Sorghum bicolor (L.) cv. Pioneer 846). Model estimates of latent heat flux (LE) were within 4% and 15% of lysimetric measurements for soybeans and sorghum, respectively. When using resistance to momentum (rD), estimates of LE for soybean were 25% greater, but for sorghum only 10% greater than when using resistance to heat transport (rH).

76:02D-009
ESTIMATING GROUNDWATER EVAPOTRANSPIRATION FROM STREAMFLOW RECORDS,
Daniel, J.F.
Geological Survey, Doraville, Georgia.
Water Resources Research, Vol. 12, No. 3, p 360-364, Ju[illegible] 1976. 5 fig, 10 ref.

Descriptors: *Evapotranspiration, *Groundwater, *Estimating, *Model studies, *Streamflow, Flow rates, Aquifer characteristics, Transmissivity, Surface-groundwater relationships, Hydrologic data, *Alabama.

An analytical solution for the evapotranspiration rate from the aquifer system of a stream basin was applied to a selected basin despite large-scale violations of assumptions for the derivation. Rates computed represent losses from the groundwater bodies and do not include losses from soil moisture. The computed rate for the 23.00 sq km basin, Indian Creek near Troy, Alabama, during April and May 1963 was 0.037 cu m/sec, or about 0.5 cm/month. Such results should be reliable enough to use in rainfall-runoff models and, in the absence of more detailed data, in areal groundwater models.

76:02D-010
EVAPOTRANSPIRATION FROM A SHORT-GRASS PRAIRIE SUBJECTED TO WATER AND NITROGEN TREATMENTS,
Lauenroth, W.K., and Sims, P.L.
Colorado State University, Natural Resource Ecology Lab, Fort Collins, Colorado.
Water Resources Research, Vol. 12, No. 3, p 437-442, June 1976. 8 fig, 1 tab, 18 ref. U.S. International Biological Program Grassland Biome. NSF GB-7824, GB-13096.

Descriptors: *Evapotranspiration, *Prairie soils, *Grasses, *Colorado, *Great Plains, Water, Nitrogen, Water balance, Soil-water-plant relationships, Energy budget, On-site inbestigations, Soil treatment.

Evapotranspiration was estimated by the water balance method for three water and nitrogen treatments and a control in a shortgrass prairie in northeastern Colorado in 1971, 1972, and 1973. Nitrogen was applied at a rate of 150 kg/ha to maintain soil mineral nitrogen levels greater than or equal to 50 kg/ha above control levels with and without supplemental water. The water treatment maintained soil water potential greater than -0.8 bar during the growing season and was applied with and without nitrogen. Evapotranspiration for the control and unwatered nitrogen treatments was not different and ranged from 118 to 226 mm over the 3 years. The 3-year averages of evapotranspiration for the water plus nitrogen treatments were 505 and 578 mm, respectively. Evapotranspiration for the water plus nitrogen treatment agreed with potential evapotranspiration predicted by Penman's model.

76:02D-011
A SIMPLE METHOD FOR DETERMINING THE EVAPORATION FROM SHALLOW LAKES AND PONDS,
Stewart, R.B., and Rouse, W.R.
Atmospheric Environment Service, Downsview, Ontario, Canada.
Water Resources Research , Vol. 12, No. 4, p 623-628, August 1976. 9 fig, 13 ref.

Descriptors: *Evaporation, *Lakes, *Energy budget, *Radiation, Ponds, Equilibrium, Solar radiation, Air temperature, Models, Equations, On-site investigations, Mathematical studies.

The summertime evaporation from a shallow lake in the Hudson Bay lowlands was evaluated by the energy budget (Bowen ratio) and equilibrium model approaches. Energy budget calculations revealed that, on the average, 55% of the daily net radiation was utilized in the evaporative process over the lake. Half-hourly and daily values of evaporation were approximated closely by the Priestly and Taylor (1972) model, where the ratio of actual-to-equilibrium evaporation equalled 1:26. A simple model, expressed in terms of incoming solar radiation and screen height air temperature, was developed from the comparison of actual-to-equilibrium evaporation. Tests of the model at a different location indicated that the actual evaporation could be determined within 10% over periods of two weeks.

76:02D-012
SENSITIVITY AND MODEL VARIANCE ANALYSIS APPLIED TO SOME EVAPORATION AND EVAPOTRANSPIRATION MODELS,
Coleman, G., and DeCoursey, D.G.
Agricultural Research Service, Chickasha, Oklahoma.
Water Resources Research, Vol. 12, No. 5, p 873-879, October 1976. 2 fig, 2 tab, 16 ref.

Descriptors: *Analytical techniques, *Mathematical models, Forecasting, *Evaporation, *Evapotranspiration, Model studies.

Variable sensitivity and error variance of six evaporation and evapotranspiration models were calculated. Their sensitivity values were computed by approximating the partial derivatives by finite differences. To compare the models, relative sensitivity was computed as the percent change in evaporation per unit change in the input variable. A second relative sensitivity was calculated to compare the relative importance of the different input variables. Error variance was analyzed to find the variance of error due to instrument inaccuracies using instrument variance estimated from the manufacturer's statements. Although no tests were conducted to determine the bias or prediction accuracy of the model, a technique was proposed to show how the instrument error variance could be added to the prediction error variance to determine the overall system variance. In model development the best model will be one whose sum of these two variances is a minimum if there is no prediction bias.

76:02D-013
THE APPLICABILITY OF PLANETARY BOUNDARY LAYER THEORY TO CALCULATE REGIONAL EVAPOTRANSPIRATION,
Brutsaert, W., and Mawdsley, J.A.
Cornell University, College of Engineering, Ithaca, New York.
Water Resources Research, Vol. 12, No. 5, p 853-858, October 1976. 4 fig, 40 ref. NSF GA-42569.

Descriptors: *Boundary layers, *Evapotranspiration, *Model studies, Evaporation, Transpiration, Water supply, Theoretical analysis, Mass transfer, Atmosphere, Atmospheric physics, Drought, Flood forecasting.

A formulation was obtained for the calculation of evapotranspiration from a region even when the water supply to the surface is limited. The theoretical model was based on general similarity principles for a steady, uniform boundary layer under any conditions of atmospheric stability. The resulting mass transfer formulae have the advantage that the necessary data (rawinsonde) are often routinely published or otherwise easily available. In contrast, most methods used for the determination of evapotranspiration require either a special experimental setup for rarely available data or are purely empirical and without a firm physical base. The proposed method could be applied in hydrologic simulation for drought studies and for the determination of antecedent moisture conditions in flood prediction.

Section V

WATER CYCLE

STREAMFLOW AND RUNOFF (GROUP 02E)

76:02E-001
DISSOLVED NUTRIENT LOSSES IN STORM RUNOFF FROM FIVE SOUTHERN PINE WATERSHEDS,
Schreiber, J.D., Duffy, P.D., and McClurkin, D.C.
United States Department of Agriculture, Department of Soil Science, Oxford, Mississippi.
Journal of Environmental Quality, Vol. 5, No. 2, p 201-205, April-June 1976.
2 fig, 6 tab, 21 ref.

Descriptors: *Runoff, Erosion, Storm runoff, Watersheds (basins), Nutrients, Sampling, Mississippi, Water quality, Precipitation, Nitrogen, Phosphorus, Cations.

Storm runoff from five reforested eroded watersheds in northern Mississippi was analyzed during the 1973 water year to determine the concentrations of soluble NO3-N, NH4-N, PO4-P, Ca, Mg, and K. Storm runoff was measured with 0.91-m H-flumes and samples collected with Coshocton wheel sampler. Analysis of precipitation which totaled 189 cm for the year, 40% above average, revealed that inputs of NO3-N, NH4-N, PO4-P, Ca, Mg, and K for the year were 3.12, 5.73, 0.07, 7.72, 3.03, and 4.98 kg/ha respectively. Soluble nutrient losses in the storm runoff on a unit area basis were similar for the five watersheds. Average losses in storm runoff of soluble NO3-N, NH4-N, PO4-P, Ca, Mg, and K for the year were 0.32, 3.35, 0.04, 6.21, 3.05, and 3.31 kg/ha respectively. As the annual storm runoff among the watersheds increased, the NO3-N losses also increased linearly. Data for individual storms indicated that a critical storm runoff value must be exceeded before the watersheds would exhibit a net loss of each nutrient.

76:02E-002
LOSS OF 2,4-D IN RUNOFF FROM PLOTS RECEIVING SIMULATED RAINFALL AND FROM A SMALL AGRICULTURAL WATERSHED,
White, A.W. Jr., Asmussen, L.E., Hauser, E.W., and Turnbull, J.W.
United States Department of Agriculture, Agricultural Research Service, Soil Science and Chemistry, Byron, Georgia.
Journal of Environmental Quality Vol. 5, No. 4, p 487-490, October-December 1976. 2 fig, 2 tab, 24 ref.

Descriptors: *2,4-D, *Runoff, Agricultural watersheds, Simulated rainfall, Surface runoff, Herbicides, Soil profiles, Water pollution, Soils, Leaching.

Movement of 2,4-D was not significant in either surface or subsurface runoff from a small agricultural watershed on a sandy Coastal Plain soil. Surface runoff levels were highest for the first runoff event after herbicide application (0.56 kg/ha) each year, and initial concentrations were related to the time lapse between herbicide application and the date of the first runoff event. Maximum concentrations were 8.1, 6.2, and 2.5 micro g/liter in 1970, 1971, and 1972, respectively. The corresponding time lapse for the same years was 20, 27, and 34 days. Persistence studies showed that the 2,4-D concentration in the surface 0.5 cm of soil decreased 95%, from 4.7 to 0.23 ppm in only 7 days, and after 34 days the soil concentration was only 0.01 ppm. Although subsurface flow was three times greater than surface runoff during the 3-year period, 2,4-D movement in subsurface water was negligible. Concentrations were usually zero or < 1 micro g/liter. Soil sampled to a 90-cm depth showed no 2,4-D accumulation or build-up in the soil profile. Simulated rains (8.25 cm in 30 min) applied to subplots on the watershed showed that there is a potential for greater 2,4-D losses in surface runoff when it rains soon after herbicide application, When rains were applied 1,8, and 35 days after herbicede application, the average 2,4-D concentrations in runoff were 25.2, 5.8, and 0.7 micro g/liter, respectively.

76:02E-003
IDENTIFICATION OF LINEAR SYSTEMS RESPONSE BY PARAMETRIC PROGRAMMING,
Neuman, S.P., and Marsily, G.D.
Arizona University, Department of Hydrology and Water Resources, Tucson, Arizona.
Water Resources Research, Vol. 12, No. 2, p 253-262, April 1976. 18 fig, 23 ref.

Descriptors: *Input-output analysis, *Hydrograph analysis, *Runoff forecasting, Analytical techniques, *Linear programming, Hydrologic systems, Hydrology, Decision making, Hydrologic data, Precipitation (Atmospheric).

The impulse response function of a linear hydrologic system is extremely sensitive to minor errors in the input-output data. Low-amplitude random errors can cause severe oscillations in the response function. Objective methods are not available for filtering the input-output data to obtain physically realizable solutions. The ultimate goal of response function identification is to determine a solution which optimizes the predictive capabilities of the linear model. An important criterion of optimality is that the shape of the response function be physically plausible. Use of parametric linear programming was proposed to achieve this objective. The problem was formulated as a multicriterion decision process under uncertainty. Parametric programming served as a means of generating a continuous set of alternative solutions to the identification problem together with a bicriterion function representing these alternatives. The shape of the bicriterion curve was then used as a guide by the hydrologist in selecting a particular solution when he is relying on his own value judgment.

76:02E-004
ISOTOPIC HYDROLOGY IN THE AMAZONIA II. RELATIVE DISCHARGES OF THE NEGRO AND SOLIMOES RIVERS THROUGH 0-18 CONCENTRATIONS,
Matsui, E., Salati, F., Friedman, I., and Brinkman, W.L.F.
Centro de Energia Nuclear na Agricultura, Sao Paulo, Brazil; and Geological Survey, Denver, Colorado.
Water Resources Research, Vol. 12, No. 4, p 781-785, August 1976. 4 fig, 2 tab, 15 ref.

Descriptors: *Streamflow, *Flow rates, *Oxygen isotopes, *Hydrology, *South America, *Precipitation (Atmospheric), Runoff, Sampling, Water analysis, Ion transport, Mixing, Tributaries.

Measurements of 0-18 were made on samples of water collected during a 2-year period on the Amazon below the confluence of the Negro and Solimoes rivers. The measurements show that the Amazon is not completely mixed 120 km below the confluence. Estimates of relative flows were based on the 0-18 concentrations and show that the relative contribution of the Negro varied from 19% in February 1973 to 68% in July 1973.

76:02E-005
MODELING MONTHLY HYDROLOGIC PERSISTENCE,
Young, G.K., and Jettmar, R.U.
Catholic University of America, Department of Civil Engineering, Washington, D.C.
Water Resources Research, Vol. 12, No. 5, p 829-835, October 1976. 5 fig, 3 tab, 7 ref, 1 append. OWRT C-3029(No. 3730)(2).

Descriptors: *Streamflow, *Persistence, *Model studies, Mathematical models, Runoff, Monthly, Analytical techniques, Statistical analysis, Correlation analysis, Streamflow forecasting, Rivers, Hydrology.

This paper reported an empirical study of the autocorrelations and Hurst parameter properties for monthly streamflow for a set of U.S. Geological Survey gaging stations in the eastern United States. The analysis was motivated by a desire to develop operational criteria to select persistence measures and generating models. The work was part of a larger effort to evaluate the trade-offs between complex and simple data generators. Markov generators are simple in comparison to the more complex self-similar methods. Monthly streamflow data were found to have Hurst statistics similar to annual data. Least squares was presented as a possible method to estimate persistence parameters and to select models. Empiric autocorrelations were treated as data in a fit of theoretic covariance functions by minimum squared error. The Hurst and least squares estimators are nearly the same. The lag 1 correlation is much smaller than least squares estimators. A step-by-step procedure was suggested for implementation of least squares persistence analysis.

76:02E-006
A DISTRIBUTED CONVERGING OVERLAND FLOW MODEL III. APPLICATION TO NATURAL WATERSHEDS,
Singh, V.P.
New Mexico Institute of Mining and Technology, Socorro, New Mexico.
Water Resources Research, Vol. 12, No. 5, p 902-908, October 1976. 8 fig, 1 tab, 13 ref.

Descriptors: *Overland flow, *Model studies, *Watersheds (Basins), Runoff, Agricultural watersheds, Parametric hydrology, Hydrology, Rainfall-runoff relationships, Mathematical studies, Equations, Flow.

The proposed distributed converging overland flow model was utilized to predict surface runoff from three natural agricultural watersheds. The Lax-Wendroff scheme was used to obtain numerical solutions. For determination of the kinematic wave friction relationship parameter, a simple relation between the parameter and topographic slope was hypothesized. The simple relation contains two constants which are optimized for each watershed by the Rosenbrock-Palmer optimization algorithm. The model results were in good agreement with runoff observations from these watersheds. It was shown that if the model structure is sound, it will suffice to optimize model parameters on hydrograph peak only, even for prediction of the entire hydrograph. The model results suggested that a distributed approach to kinematic wave modeling of watershed surface runoff is potentially promising and warrants further investigation.

76:02E-007
MORPHOMETRY AND FLOODS IN SMALL DRAINAGE BASINS SUBJECT TO DIVERSE HYDROGEOMORPHIC CONTROLS,
Patton, P.C., and Baker, V.R.
Texas University, Department of Geological Sciences, Austin, Texas.
Water Resources Research, Vol. 12, No. 5, p 941-952, October 1976. 7 fig, 12 tab, 46 ref. NWS A-35460, NASA NAS 9-13312.

Descriptors: *Texas, *Watersheds (Basins), *Geomorphology, *Floods, Drainage area, Geologic control, Drainage density, Drainage patterns (Geologic), Drainage systems, Hydrology, Flood peak.

Morphometric parameters, such as drainage density, stream magnitude, and relief ratio, are practical measures of flood potential in small (less than 100 sq mi) drainage basins. Stereoscopic interpretation of low-altitude aerial photographs provides the most accurate maps of basins for generating these parameters. Field surveys of a high-density limestone basin in central Texas showed that 1:24,000 scale topographic maps accurately portray the efficient stream channel system but fail to reveal numerous small gullies that may form portions of hillslope hydrologic systems. Flood potential in drainage basins can be defined by a regional index computed as the standard deviations of the logarithms of the annual maximum streamflows. High potential basins tend toward greater relief, greater drainage density, and, thus, greater ruggedness numbers than low-flash flood potential watersheds. For a given number of first-order channels (basin magnitude), flash flood regions have greater ruggedness numbers, indicating higher drainage densities combined with steep hillslopes and stream channel gradients. Transient controls on flood response, such as differences between local rainstorm intensities, appear to be the major influences on hydrographs in areas of moderate dissection and relief. Morphometric parameters for low-potential flash flood regions (Indiana and the Appalachian Plateau) are better estimators of frequent low-magnitude runoff events (mean annual flood), while the same parameters correlate better with the maximum flood of record in high-flood potential regions (central Texas, southern California, and north central Utah).

76:02E-008
WATER TEMPERATURE FORECASTING AND ESTIMATION USING FOURIER SERIES AND COMMUNICATION THEORY TECHNIQUES,
Long, L.L.
Tennessee Technological University, Department of Mathematics, Cookeville, Tennessee.
Water Resources Research, Vol. 12, No. 5, p 881-887, October 1976. 11 fig, 2 tab, 9 ref.

Descriptors: *Water temperature, *Analytical techniques, *Regression analysis, *Fourier analysis, Model studies, Mathematical models, Temperature, Rivers, Forecasting, Time series analysis, Statistics, Statistical methods, Mathematics.

Fourier series and statistical communication theory techniques were utilized in the estimation of river water temperature increases caused by external thermal inputs. An example estimate, assuming a constant thermal input, was demonstrated. A regression fit of the Fourier series approximation of temperature was then used to forecast daily average water temperatures. Also, a 60-day prediction of daily average water temperature was made, with the aid of the Fourier regression fit, by using significant Fourier components.

76:02E-009
A DISTRIBUTED CONVERGING OVERLAND FLOW MODEL I. MATHEMATICAL SOLUTIONS,
Sherman, B., and Singh, V.P.
New Mexico Institute of Mining and Technology, Socorro, New Mexico.
Water Resources Research, Vol. 12, No. 5, p 889-896, October 1976. 10 fig, 16 ref, 3 append.

Descriptors: *Model studies, *Mathematical models, *Overland flow, *Distribution systems, Hydrologic systems, Infiltration, Agricultural watersheds, Watersheds (Basins), Hydrology.

In models for overland flow based on kinematic wave theory, the friction parameter is assumed to be constant. This paper reported a study of a converging geometry which allows continuous spatial variability in the parameter. Parameter variability results in a completely distributed approach, reduces the need to use a complex network model to sumulate watershed surface runoff, and saves much computational time and effort. This paper was the first in a series for a converging geometry with no infiltration and with temporally constant lateral inflow. Part 2 discussed the effect of infiltration on the runoff process, and part 3 discussed application of the proposed model to natural agricultural watersheds.

76:02E-010
THE RELATIONSHIP BETWEEN LIGHT AND PHOTOSYNTHETIC RATE IN A RIVER COMMUNITY AND IMPLICATIONS FOR WATER QUALITY MODELING,
Hornberger, G.M., Kelly, M.G., and Eller, R.M.
Virginia University, Department of Environmental Sciences, Charlottesville, Virginia 22903
Water Resources Research, Vol. 12, No. 4, p 723-730, August 1976. 7 fig, 1 tab, 31 ref.

Descriptors: Photosynthesis, Aquatic environment, Aquatic habitats, Nutrients, Inhibition, Modeling, Model studies, Water quality.

Saturation of photosynthesis at naturally occurring high light intensities has widely been reported for aquatic communities. Contrary to this, using free water measurement methods, we found a relationship between light intensity and photosynthesis in a small river that was unmistakably linear on cloudless days and on days when points corresponding to times of highly variable radiation were discarded. The linear relationship obtained through the year. Simulations of nutrient-limited growth in light-dark bottles show that nutrient depletion effects can explain the cases of light saturation and inhibition previously reported in the literature. If light saturation and inhibition of photosynthesis are due even in part to artificially induced nutrient limitation, then the inclusion of nonlinear light terms in water quality models is inappropriate.

76:02E-011
COMPATIBLE SEDIMENT CONTROL PRACTICES AND TILLAGE SYSTEMS,
Tompkins, F.D., Shelton, C.H., and Temple, J.E.
Tennessee University, Department of Agricultural Engineering, Knoxville, Tennessee.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 16 p, 4 fig, 3 tab, 5 ref.

Descriptors: Sediments, Sediment control, Flow resistance, Soybeans, Runoff, Watersheds, Return flow.

The results of this study indicate that pattern efficiency for a graded system was about the same as that for the conventional cropping pattern previously used. The angle at which the rows intersect the headland affects the time required for turning. Time required for turning increases as the intersection angle increasingly deviates from 90 degrees. Soybean yields obtained after land grading were somewhat higher than the station average. This suggests that, for the study area, soil disturbance due to land grading did not adversely affect yield. For specific runoff events occurring in early spring, sediment yield per cm of runoff on the original ungraded watershed was 85 percent less when the land was planted to wheat as compared to a fallow condition. After grading, the wheat-covered land yielded only 15 percent as much sediment per cm of runoff as that produced by the original watershed in wheat. The sediment yield per cm of runoff for the graded watershed in wheat was only about 2 percent of the yield from the original fallow watershed.

76:02E-012
A PHYSICALLY-BASED MODEL TO PREDICT RUNOFF UNDER VARIABLE RAIN INTENSITY,
Hachum, A.Y. and Alfaro, J.F.
Utah State University, Agricultural and Irrigation Engineering Department, Logan, Utah.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 16 p, 1 fig, 2 tab, 31 equ, 15 ref.

Descriptors: Infiltration, Rainfall, Model studies, Simulation analysis, Rain, Rainfall intensity, Rainfall simulators, Rainfall-runoff relationships.

A review of literature revealed that there are many empirical and physically-based models that have been proposed to analyze infiltration under different rainfall conditions. However, the validity of these models is still unknown due to the lack of experimental data to support them. A simple and universal physical model capable of predicting the ponding time and the rain infiltration in soils is presented. Basically, the model is an extension of the Green and Ampt approach to analyze infiltration under variable rainfall patterns. Model applications for a storm presented elsewhere (Smith 1972) is included as well as for a hypothetical storm with a smooth-variable intensity rainfall pattern. The prediction of the system behavior, for the first case, closely agrees with that of Smith (1972).

76:02E-013
SEDIMENT YIELD PREDICTION BASED ON WATERSHED HYDROLOGY,
Williams, J.R. and Berndt, H.D.
United States Department of Agriculture, Agricultural Research Service, P.O.Box 748, Temple,Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 14 p, 3 tab, 22 equ, 12 ref.

Descriptors: Sediments, Sedimentation, Sediment yield, Model studies, Soil moisture, Texas, Rainfall, Watersheds, Watershed management, Reservoir design.

Daily, monthly, and annual sediment yield can be predicted fairly accurately by attaching a sediment yield model (MUSLE) to hydrologic models. A water yield model based on SCS curve numbers and a soil moisture index is used to predict daily runoff volumes. This model must be calibrated on a gaged watershed and can then be used to extend short periods of record for the calibrated watershed or to predict water yield for nearby ungaged watersheds. Peak flow rates are predicted for a few storms of various volumes using HYMO. To save computing time these peak flow rates are related to their runoff volumes so that the peak rate can be determined rapidly for each daily flow volume. MUSLE uses the predicted daily runoff volume and peak rate to predict daily sediment yield. The runoff-sediment model was tested on 26 watersheds in Texas. A comparison of measured and predicted average annual sediment yields gave an R2 or 0.98. For eight of the watersheds monthly measured and predicted sediment had an average R2 or 0.66. Prediction accuracy generally increased with decreasing watershed area mainly because point rainfall better represents actual rainfall as area decreases. The monthly and annual standard deviations of measured and predicted sediment yield compared closely for these eight watersheds. Close comparisons in standard deviations indicate that the predictions are fluctuating properly although they may not always agree well with measured amounts. Also the model predicted consistently throughout the year--sediment was not overpredicted for certain seasons and underpredicted for others.

76:02E-014
NUTRIENT TRANSPORT IN RUNOFF FROM SANDY SOILS,
Campbell, K.L.
Florida University, Department of Agricultural Engineering, Gainsville, Florida.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 20 p, 4 fig, 7 tab, 5 ref.

Descriptors: Watersheds, Water quality, Water quality management, Nutrients, Streamflow, Return flow, Phosphorus, Nitrogen.

Two agricultural watersheds were instrumented to determine water quantity and quality measurements. The upper watershed of 437 hectares was primarily in forest cover with some pasture. The lower watershed of 208 hectares was mostly in intensive agricultural crop production with some pasture. The following results are from data collected between July, 1975 and June, 1976. 1. Nitrogen and phosphorus loads in streamflow were about proportional to the flow volume in the two watersheds. 2. The increased flow volume in the lower watershed occurred mostly during storm periods and was probably primarily due to land use and topography differences between the two watersheds. 3. There were only small average concentration changes between storm flow periods and low flow periods in both watersheds. 4. Partial nutrient balances indicate that nutrient losses in streamflow are a very small part of the total nutrient flow system in these two watersheds. Total nitrogen and phosphorus losses in streamflow were equivalent to about 5% of the commercial fertilizer applied in each watershed. Nutrient loads in streamflow also were less than those contributed to the watersheds in precipitation during the period.

76:02E-015
A SALINITY MANAGEMENT STRATEGY FOR STREAM-AQUIFER SYSTEMS,
Helweg, O.J. and Labadie, J.W.
California University, Department of Civil Engineering, Davis, California
Hydrology Papers, Colorado State University, No. 84, p 41, February 1976. 38 fig, 11 tab, 25 ref.

Descriptors: Salt, Salinity, Irrigation, Irrigation effects, Groundwater, Model studies, Simulation Analysis, Optimization, Economics.

One of the pressing problems facing the irrigation intensive areas of the world is the increasing salinity of groundwater. Currently proposed solutions, such as agricultural sewering and desalinization, require large capital investment. There appear to be few available alternatives which are both low cost and effective in controlling aquifer degradation from irrigation drainage. The ultimate result in many areas may be abandonment of the groundwater resource and increasing dependence on more expensive imported water. Presented herein is a cost-effective salinity management technique which may be feasible for many stream-aquifer systems. The basic idea is to encourage application of pumped water downstream of the well from which it is pumped, rather than within its vicinity. In this way, a mechanism is established for accelerating the downstream transport of salts in the groundwater at a more rapid rate than would occur naturally through convection and dispersion, while still satisfying irrigation demands. The strategy is therefore referred to as the Accelerated Salt Transport (ASTRAN) Method. Salt accumulation can be controlled in this manner, while taking care that salt problems are not simply transferred downstream.

Section VI

WATER CYCLE

GROUNDWATER (GROUP 02F)

76:02F-001
STEADY NON-DARCIAN SEEPAGE THROUGH EMBANKMENTS,
Basak, P.
Punjab Agricultural University, Department of Civil Engineering, Ludhiana, India.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 102, No. IR4, Proceedings Paper No. 12623, p 435-443, December 1976.
5 fig, 2 tab, 19 ref.

Descriptors: *Darcys law, *Discharge (Water), *Free surfaces, *Seepage, *Aquifer characteristics, Drainage, Water table, Steady flow, Velocity, Analysis, Flow resistance, Porous media, Reynolds number.

A steady-state analytical solution for the case of unconfined flow through embankments incorporating Forchheimer's nonlinear velocity-gradient response was presented. The effect of nonlinearity on the discharge characteristics and drawdown distribution in relation to the corresponding Darcian case was brought out. Predicted discharge by means of the derived analytical solution was campared with the available finite difference solution and experimental results.

76:02F-002
TRANSIENT DRAINAGE WITH NONLINEARITY AND CAPILLARITY,
McWhorter, D.B., Duke, H.R.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 120, No. IR2, Proceedings Paper 12185, p 193-204, June 1976.
4 fig, 1 tab, 10 ref, 2 append.

Descriptors: *Equations, *Drainage, *Drains, *Groundwater movement, *Unsaturated flow, Water table, Mathematical models, Unsteady flow, Mathematical studies, Flow.

A nonlinear partial differential equation was developed that includes the effects of capillary storage and flow above the water table. An approximate analytic solution was derived. The water table response at the midpoint between drains affected by capillary storage flow above the water table, and the nonlinearity due to decreasing flow depth was predicted by one relatively simple expression. Indices to the degree of importance of each of these three effects were defined. It was concluded that appropriate simplified forms of the solution can be selected based on the value of the indices. The method is applicable to a wide range of conditions including drains placed at any elevation relative to the impervious substratum and for shallow as well as deep water tables. The method removes three important restrictions necessarily imposed on the classical and desirable features. The equations are sufficiently simple to permit computations with a calculator and should be useful on routine design calculations.

76:02F-003
WATER QUALITY AS RELATED TO LINEARS, ROCK CHEMISTRY, AND RAIN WATER CHEMISTRY IN A RURAL CARBONATE TERRAIN,
Wagner, G.H., Steele, K.F., MacDonald, H.C., and Coughlin, T.L.
Arkansas University, Department of Geology, Fayetteville, Arkansas.
Journal of Environmental Quality, Vol. 5, No. 4, p 444-451, October-December 1976. 4 fig, 5 tab, 12 ref.

Descriptors: Water quality, Precipitation, Rain water, Carbonate, Arkansas, Trace elements, Aquifers, Nitrate, Fertilizers, Spring waters, Wells.

Water from wells, springs, and streams from a 259 sq km area in rural, carbonate terrain of northwest Arkansas was analyzed for Na, K, Ca, Mg, NO3, PO4, and trace metals, Fe, Co, Cr, Ni, Cu, Zn, Cd, Pb, Mn, Li, and Sr. Bacterial counts for total coliform, fecal coliform, and fecal streptocci, were also made. The same area was mapped for linears by means of aerial photographs and field observations. Average rain water chemistry was determined for the year of 1974 when the various water sources were sampled. The average chemical composition of the St. Joe Limestone Member of the principal aquifer was determined from 22 samples collected in northwest Arkansas. Water sources on linears had higher nitrate and were more bacteriologically contaminated than those off linears. Trace metals pollution was negligible in all waters except for copper and zinc which were high due to contamination from household plumbing. Rain water is the main source of trace metals for wells, springs, and streams, and limestone is the main source of Ca and Mg. Rain water is a prime source of Na and K; however, clay, shale, animal waste, and agricultural fertilizer probably also contribute Na and K.

76:02G-004

ONE-DIMENSIONAL SIMULATION OF AQUIFER SYSTEM COMPACTION NEAR PIXLEY, CALIFORNIA: II. STRESS-DEPENDENT PARAMETERS,

Helm, D.C.

Geological Survey, Menlo Park, California.

Water Resources Research, Vol. 12, No. 3, p 375-391, June 1976. 12 fig, 1 tab, 22 ref.

Descriptors: *Land subsidence, *Model studies, *Aquifer systems, *California, Methodology, Aquitards, Hydraulic conductivity, Specific retention, Water storage, Compaction, Aquifer characteristics, *Simulation analysis, Computer models.

A major problem facing hydrologists is how to predict land subsidence. A key to this problem is the development of a reliable method for evaluating aquitard parameters. For assumed values of hydraulic conductivity and storage, vertical compaction and expansion of idealized aquitards can be computed (predicted) by an appropriate diffusion equation from known (projected) water level changes in adjacent aquifers. If water levels within the aquifers are observed and the resulting field compaction and expansion are measured, the parameters themselves can be evaluated. Such field measurements are available at a site near Pixley, California, for the composite behavior of a series of 21 doubly draining aquitards. By means of a linear partial differential equation with constant coefficients within one digital model, average hydraulic conductivity for idealized aquitards was evaluated from the field data to be 3,000 ft/yr, and average nonrecoverable compaction to be stress dependent by assuming for any single material that the product of hydraulic conductivity and an incremental effective stress is a constant and that the product of nonrecoverable specific storage and past maximum effective stress is a constant.

76:02F-005

DETERMINATION OF THE HYDRAULIC CONDUCTIVITY - DRAINABLE POROSITY RATIO FROM WATER TABLE MEASUREMENTS,

Skaggs, R.W.

North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, North Carolina.

Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 73-84, January-February 1976. 13 fig, 25 ref.

Descriptors: *Hydraulic conductivity, *Porosity, *Specific yield, *Water table, Drawdown, Drainage systems, Groundwater movement, Drains, Dupuit-Forcheimer theory, Equations, Numerical analysis, Computers, Measurement, Graphical analysis, Heterogeneity, Anisotropy, Evapotranspiration, Saturated flow.

A method was presented for determining field effective values of the hydraulic conductivity-drainable porosity (K/f) ratio from water table measurements. Solutions were presented in graphical form for parallel drains and for a single drain in a semi-infinite medium. K/f can be determined from these solutions from either water table drawdown or rise measurements. Solutions were also presented for simultaneous drainage and vertical losses and may be used to evaluate the effect of evapotranspiration or deep seepage on K/f determinations. Errors due to unaccounted vertical losses can be minimized by making water table measurements close to the drain.

76:02F-006
A THREE-DIMENSIONAL GALERKIN FINITE ELEMENT SOLUTION OF FLOW THROUGH MULTIAQUIFERS IN SUTTER BASIN, CALIFORNIA,
Gupta, S.K., and Tanji, K.K.
California University, Department of Water Science and Engineering, Davis, California.
Water Resources Research, Vol. 12, No. 2, p 155-162, April 1976. 6 fig, 1 tab, 9 ref. (Project UCAL-WRC-W438).

Descriptors: *Leakage, *Aquitards, Model studies, *Finite element analysis, *California, Aquifers, Groundwater movement, Groundwater basins, Heterogeneity, Dissolved solids, Connate water, Water quality, Digital computers, Equations, Groundwater, Data processing, Faults (Geologic), Hydraulic conductivity, Water table, Aquifer systems.

A three-dimensional finite element solution was obtained for the simultaneous consideration of multiaquifers coupled through semiconfining layers, and the model was applied to a groundwater regime in Sutter Basin, California. The use of a disk/tape in data handling and computation has reduced the core storage and processor time and increased the capability of a given computer system to simulate basins larger than are presently possible with the use of only core storage. This economy was achieved by storing on a disk/tape all the intermediate results which are needed repeatedly. On the Burroughs B6700 each steady state solution of 123 three-dimensional elements and 232 nodes was obtained with 20 kbit of memory and 1.49 min of processor time.

76:02F-007
THEORY OF MULTIPLE LEAKY AQUIFERS I. THE INTEGRODIFFERENTIAL AND DIFFERENTIAL EQUATIONS FOR SMALL AND LARGE VALUES OF TIME,
Rodarte, L.
Universidad Nacional Autonoma de Mexico, Instituto de Ingenieria, Mexico City, Mexico.
Water Resources Research, Vol. 12, No. 2, p 163-170, April 1976. 2 fig, 16 ref.

Descriptors: *Leakage, *Aquifers, *Aquicludes, *Aquitards, *Mathematical models, Equations, Theoretical analysis, Mathematical studies, Drawdown, Water wells, Pumping, Permeability, Aquifer systems, Elasticity (Mechanical), Time, Artesian heads.

The general problem of multiple leaky aquifers was analyzed by using a particular problem as a starting point. Differential and integrodifferential equations for small and large values of time, valid for the analysis of multiple leaky aquifers, were obtained. The proposed equations are appropriate for both the numerical and the analytic treatment of the regional evolution of the piezometric loads.

76:02F-008
ON THE GENERAL EQUATIONS FOR FLOW IN POROUS MEDIA AND THEIR REDUCTION TO DARCY'S LAW,
Gray, W.G., and O'Neill, K.
Princeton University, Department of Civil Engineering, Princeton, New Jersey.
Water Resources Research, Vol. 12, No. 2, p 148-154, April 1976. 1 fig, 15 ref, append. NSF ENG75-16072 and NSF-RANN 6064.

Descriptors: *Groundwater, Equations, *Darcy's Law, Mathematics, *Flow, Subsurface waters, Groundwater movement, Groundwater potential, Pore water, Energy equation, Momentum equation, Mathematical studies, *Porous media, Mass transfer, Convection, Dispersion.

A technique of local averaging was applied to obtain general equations which describe mass and momentum transport in porous media. The averaging was performed without significantly idealizing either the porous medium or the pertinent fluid mechanical relations. The resulting general flow equation was simplified to treat flow of a Newtonian fluid in a slowly deforming solid matrix for two special cases. For flow in an isotropic medium where convective and inertial terms are important, an equation was developed which is dependent only on five medium parameters which could be evaluated by experiment. Flow in an anisotropic medium was also analyzed, and the general equation was reduced to Darcy's law when the convective and inertial terms were neglected.

76:02F-009
THE EXTENDED BOUSSINESQ PROBLEM,
Collins, M.A.
Southern Methodist University, Institute of Technology, Dallas, Texas.
Water Resources Research, Vol. 12, No. 1, p 54-56, February 1976. 5 fig, 1 ref.

Descriptors: *Water table, *Drains, *Groundwater movement, Leakage, Groundwater recharge, Saline water-freshwater interfaces, Aquifers, Groundwater, Continuity equation, Dupuit-Forchheimer theory, Boundary processes, Potentiometric level, Equations, Islands, Depth.

The original Boussinesq problem of the decline of a groundwater mound between parallel drains was extended to include vertical leakage and recharge and cases of freshwater lenses in confined and unconfined saline aquifers. The solution of appropriate continuity equations with some imposed restrictions by variable separation resulted in three distinct flow depth configurations, which could be described analytically. Transient behavior in two of these cases is nonlinear but amenable to exact solution and can be delineated in a (2 mu + beta, sigma + mu) plane, where beta and sigma are leakage and recharge parameters and mu is a separation constant. It was found that similarity solutions, one of which is the original Boussinesq solution, exist for both decreasing and increasing flow depths. Active and passive influences of boundary conditions were distinguished. Solutions were applied to the evaluation of saline water intrusion in some coastal zones of Long Island, New York.

76:02F-010
FLOW INTERFERENCE EFFECTS AT FRACTURE INTERSECTIONS,
Wilson, C.R., and Witherspoon, P.A.
Leeds, Hill, and Jewett, Incorporated, San Francisco, California.
Water Resources Research, Vol. 12, No. 1, p 102-104, February 1976. 4 fig, 1 ref.

Descriptors: *Groundwater movement, *Fracture permeability, *Model studies, Hydraulic models, Flow, Laminar flow, Fractures (Geologic), Cracks, Rocks, Hydrology, Hydraulics, Laboratory tests, Hydrogeology, Subsurface waters, Groundwater.

A series of laboratory experiments were conducted to determine the magnitude of laminar flow interference effects at fracture intersections. Circular conduits were used in these experiments to maintain strict dimensional tolerance, and the intersection head loss, if expressed in terms of equivalent length of straight conduit, should be the same order of magnitude for a circular pipe as for a parallel plate fracture model. The results indicated that interference effects at intersections are negligibly small in most fracture systems when flow is in the laminar regime.

76:02F-011
DETERMINING AQUIFER TRANSMISSIVITY BY MEANS OF WELL RESPONSE TESTS: THE UNDERDAMPED CASE,
van der Kamp, G.
Department of the Environment, Inland Waters Directorate: and Department of the Environment, Hydrology Research Division, Ottawa, Ontario, Canada.

Water Resources Research, Vol. 12, No. 1, p 71-77, February 1976. 2 fig, 3 tab, 7 ref.

Descriptors: *Aquifer testing, *Transmissivity, *Theoretical analysis, Aquifer characteristics, Water levels, Well filters, Equilibrium, Equations, Water level fluctuations, Well casings, Aquifers, Artesian heads, On-site data collections.

Well response tests, often referred to as slug tests, provide a relatively simple and inexpensive method for estimating aquifer transmissivity. An approximate theory was developed for the problem of underdamped well response where the inertia of the water in the well column results in force-free oscillation of the water level in the well. This type of response is often encountered in conjunction with highly permeable aquifers. The theory is applicable for nearly all such cases except those where the oscillation is very quickly damped out. Theoretical predictions compared well with empirical results and indicated that the theory may be used to obtain estimates of aquifer transmissivity. This theory for the underdamped case together with existing theory for overdamped response makes it possible to obtain an estimate of transmissivity from well response tests for almost any aquifer.

76:02F-012
TRANSIENT FREE SURFACE FLOW TO A WELL: AN ANALYSIS OF THEORETICAL SOLUTIONS,
Gambolati, G.
Centro di Ricerca IBM di Venezia, Italy.
Water Resources Research, Vol. 12, No. 1, p 27-39, February 1976. 12 fig, 1 tab, 59 ref.

Descriptors: *Unsteady flow, *Water table aquifers, *Equations, Storage coefficient, Specific yield, Water wells, Drawdown, Groundwater, Stress, Pressure head, Theis equation, Dupuit-Forchheimer theory.

Results based on linearization and on the delayed yield concept provide the most theoretical advancements to date for solving the differential equations of transient free surface flow to a fully penetrating gravity well. If the storage coefficient is markedly less than the specific yield, vertical flow is predominant in a cylindrical zone of the water table between two regions where flow is essentially radial and controlled by two different Theis equations. The true physical alpha (reciprocal of Boulton's delay index) is found to vary almost linearly with the reciprocal of the distance from the pumped well and becomes a constant at some distance (equal to twice the aquifer thickness if the medium is isotropic). An empirical delay index is also found by equating Boulton's solution and the linearized average drawdown. Its expression enables the use of the delayed yield solution in computing average drawdowns with an accuracy equal to that of the linearization approach. The present solutions assumed small water table drawdowns and an infinite aquifer.

76:02F-013
AN INTEGRATED FINITE DIFFERENCE METHOD FOR ANALYZING FLUID FLOW IN POROUS MEDIA,
Narasimhan, T.N., and Witherspoon, P.A.
California University, Department of Civil Engineering, Berkeley, California.
Water Resources, Research, Vol. 12, No. 1, p 57-64, February 1976. 10 fig, 30 ref.

Descriptors: *Numerical analysis, *Groundwater movement, *Porous media, Heat transfer, Stability, Conduction, *Finite element analysis, Flow, Equations, Potential flow, Theis equation, Fracture permeability, Mathematical studies, Computers.

The theoretical basis for the integrated finite difference method (IFDM) was presented to describe a powerful numerical technique for solving problems of groundwater flow in porous media. The method combines the advantages of an integral formulation with the simplicity of finite difference gradients and is very convenient for handling multidimensional heterogeneous systems composed of isotropic materials. Three illustrative problems were solved to demonstrate that two- and three-dimensional problems are handled with equal ease. Comparison of IFDM with the wellknown finite element method (FEM) indicated that both are conceptually similar and differ mainly in the procedure adopted for measuring spatial gradients. The IFDM includes a simple criterion for local stability and an efficient explicit-implicit iterative scheme for marching in the time domain. If such a scheme can be incorporated in a new version of FEM, it should be possible to develop an improved numerical technique that combines the inherent advantages of both methods.

76:02F-014
DYNAMIC RESPONSE OF AQUIFER SYSTEMS TO LOCALIZED RECHARGE,
Cabrera, G., and Marino, M.A.
Chile University, Centro de Recursos Hidraulicos, Santiago, Chile.
Water Resources Research, Vol. 12, No. 1, p 49-63, February 1976. 7 fig,
18 ref.

Descriptors: *Recharge, *Streams, *Aquifers, *Finite element analysis, *Computer programs, Surface-groundwater relationships, Numerical analysis, Hydraulics, *Flow system, *Model studies, Analytical techniques, Base flow.

The response of stream-unconfined aquifer systems to localized recharge was investigated by means of a two-dimensional finite element model. A variational approach was used in conjunction with the finite element method to solve the ground-water flow equation. Linear approximated triangular elements were used to calculate the hydraulic head distribution in the flow region. The Crank-Nicholson centered scheme of numerical integration was employed to approximate the time derivative in the flow equation. A computer program was developed to calculate the hydraulic head distribution in the flow region. Solutions provided by the finite element model should prove useful in the evaluation of quantitative and qualitative changes in aquifer systems due to natural or artificial recharge. In addition, they should prove useful in the study of irrigation and drainage problems.

6:02F-015
ONE-DIMENSIONAL SIMULATION OF AQUIFER SYSTEM COMPACTION NEAR PIXLEY, CALIFORNIA: II. STRESS-DEPENDENT PARAMETERS,
Helm, D.C.
Geological Survey, Menlo Park, California.
Water Resources Research, Vol. 12, No. 3, p 375-391, June 1976. 12 fig, 1 tab,
22 ref.

Descriptors: *Land subsidence, *Model studies, *Aquifer systems, *California, Methodology, Aquitards, Hydraulic conductivity, Specific retention, Water storage, Compaction, Aquifer characteristics, *Simulation analysis, Computer models.

A major problem facing hydrologists is how to predict land subsidence. A key to this problem is the development of a reliable method for evaluating aquitard parameters. For assumed values of hydraulic conductivity and storage, vertical compaction and expansion of idealized aquitards can be computed (predicted) by an appropriate diffusion equation from known (projected) water level changes in adjacent aquifers. If water levels within the aquifers are observed and the resulting field compaction and expansion are measured, the parameters themselves can be evaluated. Such field measurements are available at a site near Pixley, California, for the composite behavior of a series of 21 doubly draining aquitards. By means of a linear partial differential equation with constant coefficients within one digital model, average hydraulic conductivity for idealized aquitards was evaluated from the field data to be 3000 ft/yr, and average nonrecoverable specific storage was evaluated to be 0.00023 ft. A second model allows parameters of nonrecoverable compaction to be stress dependent by assuming for any single material that the product of hydraulic conductivity and an incremental effective stress is a constant and that the product of nonrecoverable specific storage and past maximum effective stress is a constant.

76:02F-016
ANALYSIS OF AQUIFER-AQUITARD FLOW,
Streltsova, T.D.
Birmingham University, Department of Civil Engineering, Birmingham, England.
Water Resources Research, Vol. 12, No. 3, p 415-422, June 1976. 8 fig, 15 ref.

Descriptors: *Equations, *Aquifers, *Aquitards, *Groundwater movement, *Drawdown, Water wells, Water table, Leakage, Flow system, Hydraulic properties, Graphical analysis, Mathematical studies, Permeability, Storage coefficient, Specific yield, Flow.

The general drawdown equation and its particular cases were considered for a partially penetrating well discharging at a constant rate from an aquifer which is overlain by an aquitard containing the water table. An identity was established between the exact solutions, developed in terms of the rho = mu(r)/h parameter, and those based on the finite difference approximation, developed in terms of the r/B parameter. The relations in the rho and the r/B parameter were given for a well of complete penetration. The quasi-steady drawdown equation was developed for a well of partial penetration in an aquifer-aquitard flow system. The solution was graphically presented, and its use in the distance-drawdown curve-matching procedure was described. Determination of the aquifer-aquitard formation constants was discussed.

76:02F-017
A PROPOSED ALGORITHM FOR THE SOLUTION OF THE LARGE-SCALE INVERSE PROBLEM IN GROUNDWATER,
Chang, S., and Yeh, W.W-G.
California University, Department of Engineering Systems, Los Angeles, California.
Water Resources Research, Vol. 12, No. 3, p 365-374, June 1976. 4 fig, 7 tab, 23 ref. (California Water Resources Center project W290).

Descriptors: *Algorithms, *Groundwater, Flow, *Mathematical models, Constraints, Equations, Least squares method, Systems analysis, *Model studies, *Base flow.

A new algorithm is introduced for the solution of the problem of parameter identification associated with a two-dimensional unsteady state groundwater flow. The parameters to be identified are functions of the space variables. It is assumed that some observations on the dependent variable of the governing equation are available. The unknown parameters are directly identified from observations. An implicit finite difference scheme is used to approximate the original partial differential equation. A least squares criterion function is employed. The identification problem is then formulated as a standard quadratic programming representation by quasi-linearization. The formulation is further modified by a simple matrix operation which drastically reduced the dimension of the constraint set. The new algorithm is shown to be very effective in solving the large-scale inverse problem, and it is easily implemented, rapidly convergent, and able to handle any inequality constraints, a feature that is essential for such a problem.

76:02F-018
HYDRODYNAMICS OF GROUNDWATER FLOW IN A FRACTURED FORMATION,
Streltsova, T.D.
Birmingham University, Department of Civil Engineering, Birmingham, England.
Water Resources, Research, Vol. 12, No. 3, p 405-414, June 1976. 9 fig, 3 tab, 31 ref, 1 append.

Descriptors: *Groundwater movement, *Hydrodynamics, *Equations, *Fractures (Geologic), Hydraulic properties, Aquifers, Aquitards, Elasticity (Mechanical), Homogeneity, Heterogeneity, Drawdown, Testing, Pumping, Porous media, Fissures (Geologic), Graphical analysis, Mathematical studies, Rock properties.

Hydrodynamical aspects of groundwater flow in fractured formations and the basic hydraulic properties controlling the flow were considered. A brief literature survey on studying the physical characteristic of the fractured rocks and on developing an understanding on the mechanism of fluid flow in fracture formations constituted an introductory section. Basic definitions, relations, and assumptions given for subsequent interpretation of the flow behavior in a fissured rock then followed. Concepts of fractured, homogeneous, and heterogeneous water-bearing formations and their response mechanism to a pressure change were considered. The general differential equations for a flow in a fractured and in a heterogeneous formation of uniform anisotropy were derived. Two types of the flow behavior, fissure flow and pore flow, were distinguished. Two drawdown equations, respectively, for a flow in a fissure space, whether void or infilled with a fine material, and for a flow in a porous space to a well discharging at a constant rate in a fractured aquifer, were given. A fractured reservoir response to a pressure change due to pumping was illustrated by the field drawdown and recovery data. A particular case of a heterogeneous formation, an aquifer-aquitard system, was discussed, and the drawdown distribution in both aquifer and aquitard was given when account is taken of their elastic properties.

76:02F-019
A SLUG TEST FOR DETERMINING HYDRAULIC CONDUCTIVITY OF UNCONFINED AQUIFERS WITH COMPLETELY OR PARTIALLY PENETRATING WELLS,
Bouwer, H., and Rice, R.C.
Agricultural Research Service, Water Conservation Lab, Phoenix, Arizona.
Water Resources Research, Vol. 12, No. 3, p 423-428, June 1976. 4 fig, 11 ref.

Descriptors: *Hydraulic conductivity, *Aquifer testing, *Aquifers, *Water wells, *Theims equation, Water levels, Resistance networks, Analog models, Equations, Transmissivity, Water table aquifers, Water table, Potentiometric level, Permeability, Equilibrium.

A procedure was presented for calculating the hydraulic conductivity of an aquifer near a well from the rate of rise of the water level in the well after a certain volume of water is suddenly removed. The calculation was based on the Thiem equation of steady state flow to a well. The effective radius R sub e over which the head difference between the equilibrium water table in the aquifer and the water level in the well is dissipated was evaluated with a resistance network analog for a wide range of system geometries. An empirical equation relating R sub e to the geometry of the well and aquifer was derived. It was discovered that the technique is applicable to completely or partially penetrating wells in unconfined aquifers; it can also be used for confined aquifers that receive water from the upper confining layer. The method's results were compatible with those obtained by other techniques for overlapping geometries.

76:02F-020
PREDICTION OF MOUND GEOMETRY UNDER RECHARGE BASINS,
Singh, R.
San Jose State University, San Jose, California.
Water Resources Research, Vol. 12, No. 4, p 775-780, August 1976. 8 fig, 17 ref.
NSF GK-18526

Descriptors: *Groundwater recharge, *Unsteady flow, *Laplaces equation, Recharge, Mathematical studies, Water table, Porous media, Dimensional analysis, Analysis, Computers, Groundwater, Graphical analysis, Equations.

Design of recharge facilities close to urban centers required determination of the transient water table in the vicinity of the recharge site. This involves solution of the Laplace equation subject to appropriate boundary and initial conditions which are nonlinear and extremely complex for a phreatic surface with or without accretion. Previous solutions have been obtained either by linearization of the phreatic surface conditions or by utilization of other simplifying assumptions. These solutions are usually inapplicable in regions with steep hydraulic gradients. A technique for computing the transient location of the water table under finite width longitudinal and circular recharge basins was developed. The technique avoided limiting assumptions and linearization. The computations were carried out on a digital computer. Results were presented graphically and compared with other solutions where appropriate.

76:02F-021
ON THE SPECIES TRANSPORT EQUATION FOR FLOW IN POROUS MEDIA,
Blake, T.R., and Garg, S.K.
Systems, Science, and Software, La Jolla, California.
Water Resources Research, Vol. 12, No. 4, p 748-750, August 1976. 7 ref. NSF/RANN GI-44212.

Descriptors: *Porous media, *Continuity equation, *Theoretical analysis, Diffusion, Mixing, Equations, Analysis, Fluid mechanics, Momentum equation, Flow, Convection, Solutes.

A derivation of the species transport equation for flow through porous media was presented. In this study, which was based on the space-averaging formalism developed by Anderson and Jackson, the effects of both flow field fluctuations and tortuosity as well as the influence of solute transport at the fluid-solid interfacial boundary were examined.

76:02F-022
A NUMERICAL STUDY OF CONFINED-UNCONFINED AQUIFERS INCLUDING EFFECTS OF DELAYED YIELD AND LEAKAGE,
Ehlig, C., and Halepaska, J.C.
Kansas State Geological Survey, Lawrence, Kansas.
Water Resources Research, Vol. 12, No. 6, ; 1175-1183, December 1976. 13 fig, 13 ref.

Descriptors: *Groundwater, *Aquifers, *Model studies, Mathematical models, Pumping, Drawdown, Confined water, Wells, Water wells, Hydraulic conductivity, Water yield, Leakage, Transmissivity, Permeability, Groundwater movement.

A numerical model is presented in radial coordinates for a well penetrating a homogeneous isotopic aquifer of constant thickness. The model defined variations in the transmissivity and effective storage coefficient as functions of the potential. This allowed an approximation for the problem of a well pumping in an initially confined system, which becomes unconfined near the well as the potential surface drops below the confining layer of the aquifer (confined-unconfined problem). The model was used to investigate effects of delayed yield and leakage confined-unconfined aquifers. Drawdown versus time curves were presented for a variety of boundary conditions. Results showed that the conditions producing an inflection in the drawdown versus curves are not unique and illustrates the difficulty in attempting to determine aquifer characteristics from pumping test.

76:02F-023
A SINGLE-POTENTIAL SOLUTION FOR REGIONAL INTERFACE PROBLEMS IN COASTAL AQUIFERS,
Strack, O.D.L.
Minnesota University, Department of Civil and Mineral Engineering, Minneapolis, Minnesota.
Water Resources Research, Vol. 12, No. 6, p 1165-1174, December 1976. 11 fig, 15 ref.

Descriptors: *Saline water intrusion, *Saline water-freshwater interfaces, *Aquifers, *Coasts, Groundwater, Groundwater movement, Model studies, Mathematical models, Sea water, Equations, Wells, Water wells, Brackish water, Interfaces, Subsurface waters.

An analytic technique for solving three-dimensional interface problems in coastal aquifers was presented. Restriction was made to cases of steady state flow with homogeneous isotopic permeability where the vertical flow rates can be neglected in relation to the horizontal ones. The aquifer was divided into zones defined by the type of flow occurring. These types of flow may be either confined, unconfined, confined interface, or unconfined interface flow, where the interfaces separate freshwater from salt water at rest. The technique is based upon the use of a single potential which is defined throughout all zones of the aquifer. The potential is single valued and continuous throughout the multiple-zone aquifer, and its application does not require that the boundaries between the zones be known in advance. The use of the single-valued potential was illustrated for an analytical technique, but it may be used with some advantage in numerical methods such as finite difference or finite element techniques. Applications discussed involve two interface flow problems in a shallow coastal aquifer with a fully penetrating well. The first problem is one of unconfined interfaces flow where the upper boundary is a free water table. The second is one of unconfined interface flow where the upper boundary is horizontal and inpervious. Each problem involves two zones. One zone is adjacent to the coast and is bounded below by an interface between freshwater and salt water at rest. The other zone is bounded below by an impervious bottom.

76:02F-024
MAJOR CARBON 14 ANOMALY IN A REGIONAL CARBONATE AQUIFER: POSSIBLE EVIDENCE FOR MEGASCALE CHANNELING, SOUTH CENTRAL GREAT BASIN,

Winograd, I.J., and Pearson, F.J. Jr.
Geological Survey, Water Resources Division, Reston, Virginia.
Water Resources Research, Vol. 12, No. 6, p 1125-1143, December 1976.

Descriptors: *Geochemistry, *Water qualtiy, *Groundwater, *Springs, *Carbonate rocks, Aquifers, Faults (Geologic), Nevada, Trace elements.

The carbon 14 content of groundwater at the center of a 16-km-long fault-controlled spring line at Ash Meadows in south-central Nevada is 5 times greater than that in water from other major springs along the lineament. The difference in carbon 14 stands in marked contrast to the near identity of all springwaters in alkalinity, pH, carbon 13, oxygen 18, deuterium, tritium, and other major and trace ions. The possible explanations of this major carbon 14 anomaly are evaluated by using all available chemical and isotopic data from basin-wide wells and upland springs tapping the regional carbonate aquifer discharging at Ash Meadows. The four most plausible hypotheses require the presence of a major longitudinal heterogeneity in the distal portion of the groundwater basin to explain the anomaly. Flow channeling with an amplitude of at least 11 km is indicated. The simplifying assumption commonly used in simulation of basin-wide flow through fractured or solution-riddled aquifers, namely, that the aquifer is "homogenous in its heterogeneity" is not applicable to the dense fractured Paleozoic carbonate rocks comprising the Nevada aquifer; heterogeneities in this aquifer do not cancel each other areally.

76:02F-025
DUPUIT-FORCHHEIMER AND POTENTIAL THEORIES FOR RECHARGE FROM BASINS,
Brock, R.R.
California State University, Department of Civil Engineering, Fullerton, California.
Water Resources Research, Vol. 12, No. 5, p 909-911, October 1976. 5 fig, 9 ref. OWRT C-3112(3687)(3).

Descriptors: *Dupuit-Forchheimer theory, *Potential flow, *Groundwater recharge, *Pit recharge, Artificial recharge, Water table, Equations, Groundwater movement, Theoretical analysis, Water level fluctuations, Water table aquifers, Groundwater basins, Percolation, Pores, Mathematical models.

Artificial groundwater recharge from strip and square basins to an unconfined aquifer was investigated. The classical Dupuit-Forchheimer (DF) theory and the most exact potential theory were used to determine the motion of the water table resulting from recharge. For each theory, both a linear and a nonlinear version were considered. Finite difference schemes were employed to solve for the nonlinear models. Analytical solutions exist for the linear models. By comparing the results from the various theories and from experimental results in a sand model, the range of validity of the theories was determined. For sufficiently shallow flows, the DF theories gave results that are good approximations to the potential theories. For sufficiently deep flows, the potential theories must be used, particularly beneath the basin and for small times. The velocity field near a strip basin was determined from the nonlinear potential theory for both a deep and a shallow flow. Tabular results were presented that can be used to determine the rise of the water table for strip and square basins.

76:02F-026
NUMERICAL PREDICTIONS OF TWO-DIMENSIONAL TRANSIENT GROUNDWATER FLOW BY THE METHOD OF CHARACTERISTICS,
Wiggert, D.C., and Wylie, E.B.
Michigan State University, Department of Civil Engineering, East Lansing, Michigan.
Water Resources Research, Vol. 12, No. 5, p 971-977, October 1976. 12 fig, 1 tab, 31 ref. OWRT A-067-MICH(2).

Descriptors: *Groundwater movement, *Model studies, *Mathematical models, Groundwater, Aquifers, Analytical techniques, Finite element analysis, Numerical analysis, Base flow, Subsurface waters, Hydrogeology, *Forecasting.

Unsteady flow in a confined or leaky aquifer can be analyzed by replacing the two-dimensional space domain with a latticework of line elements which intersect at nodal points. Continuity and momentum principles were applied to each line element separately, resulting in a system of hyperbolic equations which can be solved by the method of characteristics. Upon combination of the continuity relation and compatibility conditions at each node, an explicit solution for the time-variable piezometric heads and seepage velocities was obtained. An inertial multiplier was introduced in the momentum equation, which varies inversely with the magnitude of the fluid acceleration. The time step, proportional to the multiplier, thus assumes large values, while the method continues to provide accurate, stable results. Numerical examples were compared with analytical solutions, and a nonhomogeneous regional aquifer analysis agreed favorably with a finite element model. The numerical scheme provides ease of programming, reduced computer storage requirements, and reasonable central processing times.

76:02F-027
HYDROGEOPHYSICAL EQUIVALENCE OF WATER SALINITY, POROSITY AND MATRIX CONDUCTION IN ARENACEOUS AQUIFERS,
Worthington, P.F.
National Physical Research Laboratory, Geophysics Division, Pretoria, South Africa.
Ground Water, Vol. 14, No. 4, p 224-232, July-August 1976. 4 fig, 9 ref.

Descriptors: *Resistivity, *Salinity, *Porosity, *Sand aquifers, Sands, Sandstones, Geophysics, Aquifer characteristics, Sodium chloride, Conduction, Equations, Groundwater, Mapping, Curves, Heterogeneity, Graphical analysis, Hydrogeology.

The value of the electrical resistivity method as a quantitative indicator of groundwater resistivity, porosity, and effective matrix resistivity was examined through the equivalence of these parameters as manifested in the surface-measured resistivity of heterogeneous water-saturated sands. It was demonstrated that, where there were unknown variations in porosity, the mapping of groundwater resistivity was most feasible at lower salinities and where porosity was relatively high. Porosity could be determined most exactly at lower values and where groundwater salinity was relatively high. Both of these approaches became less efficient as matrix conduction increases. The mapping of effective matrix resistivity was best effected at lower values where this parameter could be approximately monitored against moderate variations in both porosity and groundwater resistivity. In general, however, where there were unknown and pronounced variations in any two of these parameters, the geoelectrical determination of the third could be so ambiguous that the uncertainty in the estimated value of this parameter could exceed the total range of values encountered in an entire formation.

76:02F-028
EVALUATING GROUND-WATER PATHS USING HYDRAULIC CONDUCTIVITIES,
Naney, J.W., Kent, D.C., and Seely, E.H.
Agricultural Research Service, Chickasha, Oklahoma, Texas-Oklahoma Area.
Ground Water, Vol. 14, No. 4, p 205-213, July-August 1976. 14 fig, 13 ref.

Descriptors: *Hydraulic conductivity, *Groundwater, *Oklahoma, *Groundwater movement, *Hydrogeology, Effluent streams, Flow nets, Mathematical models, Watersheds (Basins), Subsurface flow, On-site investigations, Computer programs, Potentiometric level, Seepage, Mapping, Cores, Pump testing, Particle size, Permeameters, Model studies.

A method was presented for selecting groundwater flow paths by comparing modeled and measured hydraulic conductivity distributions. A flow chart was included which shows the steps followed in selecting the concept of roundwater flow which best fits measured hydrogeologic conditions. Both noneffluent and effluent stream conditions were evaluated using the method. Residual maps of hydraulic conductivity were used to show how modeled hydraulic conductivity may be as much as 300 times that expected when the wrong concept is used. Flow nets of modeled and measured data downstream from a flood-water-retarding structure were developed using the selected hydrogeologic conditions. Fitting hydraulic conductivity data resulted in a distribution of groundwater flow paths which better represent actual flow conditions. The method provided a unique means of calibrating a model in a pilot test area and applying it to geologically similar nearby watersheds. It was also useful for checking paths of subsurface flow where flow distribution is important as it is in the movement of chemical pollutants or nutrients from a source of recharge, such as a watershed impoundment, to downstream waters.

76:02F-029
A SIMPLIFIED APPROACH FOR THE ANALYSIS OF UNSTEADY FLOW TO A CAVITY WELL,
Kanwar, R.S., Khepar, S.D., Chauhan, H.S., and Das, G.
Punjab Agricultural University, Department of Soil and Water Engineering, Ludhiana (India).
Ground Water, Vol. 14, No. 2, p 101-105, March-April 1976. 3 fig, 1 tab, 9 ref.

Descriptors: *Groundwater, (Model studies, *Wells, *Aquifer characteristics, Aquifers, Hydraulic conductivity, Storage coefficient, Unsteady flow, Drawdown, Hydraulics.

An analytical solution obtained for unsteady flow to a cavity well has been simplified for finding the aquifer characteristics. In the analysis presented, the relationships become fairly simple for the close approximation of the unsteady state solution. The simplified solution is of great importance for finding the values of storage coefficient and hydraulic conductivity. This solution has large important economic implications, since the formation constants of the aquifer can be found without drilling in the aquifer and installing the screens. If the values of S and K found from these relations are fairly satisfactory after a pumping test, the other more expensive methods which require a fully penetrating well may not be needed.

76:02F-030
SHAPES OF STEADY STATE PERCHED GROUNDWATER MOUNDS,
Khan, M.Y., Kirkham, D., and Handy, R.L.
Iowa State University, Department of Agronomy, Ames, Iowa 50011
Water Resources Research, Vol. 12, No. 3, p 429-436, June 1976. 6 fig, 2 tab, 21 ref.

Descriptors: Groundwater, Groundwater barriers, Groundwater resources, Aquifers, Groundwater recharge, Flow nets.

A potential theory flow solution for the potential function, stream function, and shape of the water table is given for a class of steady state two- and three-dimensional perched groundwater mounds formed under a long rectangular recharge basin or under a circular recharge basin. The solutions are done by a Gram-Schmidt method and a simple iteration scheme. The mounds are formed in a stratum of conductivity k1 overlying a perching stratum of much lower conductivity k2. Capillary fringe effects are neglected. The recharge rate is R. Potential theory mound heights are compared with those given by the Dupuit-Forchheimer (DF) theory. For the cases computed, the DF theory gives apex heights of mounds correct to better than 7% for two-dimensional mounds. For three-dimensional mounds the DF theory gives in one case a mound height that is 69% too low and in another case a mound height that is 28% too low. Profiles of the computed mounds are graphed, and examples of use of the graphs in applications are given. Sample flow nets are presented.

76:02F-031
DRAINAGE PRACTICE IN IMPERIAL VALLEY, CALIFORNIA,
Hermsmeier, L.F.
Imperial Valley Conservation Research Center, Department of Agricultural Engineering, Brawley, California.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 20 p, 7 tab, 13 ref.

Descriptors: California, Drainage, Drainage practices, Salinity, Return flow, Crop production, Irrigation water, Seepage.

Some of the unique equipment and procedures developed during the past 50 years that have provided both low cost and effective drainage in the Imperial Valley is described. In this valley, as in most irrigated areas, land drainage is essential to provide the salinity and water table control necessary for good crop production. At present and in the future, increasing salinity and limited quantity of irrigation water, restrictions on quantity and the amount of contaminants in outflow and seepage water, and the need to provide improved growing conditions are presenting new challenges for drainage design and construction. These challenges and possible solutions are discussed.

76:02F-032
WATER-TABLE MANAGEMENT,
Wenberg, R.D.
United States Soil Conservation Service, South Technical Service Center, Fort Worth, Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 7 p, 4 fig, 14 ref.

Descriptors: Drainage, Irrigation, Humid areas, Subsurface drainage, Subsurface irrigation, Water table.

Water-table management as presented here is a combination of drainage and irrigation for the humid section of the United States. Subsurface drainage is used to lower the water table in coarse-textured soils and yields are improved by subsurface irrigation.

76:02F-033
UNSTEADY FLOW TO A NONPENETRATING ARTESIAN WELL,
Abdul Khader, M.H., and Ramadurgaiah, D.
Singapore University, Department of Civil Engineering, Singapore-10, Singapore.
Groundwater, Vol. 14, No. 4, p 200-204, July-August 1976. 5 fig, 2 tab, 9 ref.

Descriptors: Artesian wells, Groundwater, Aquifers, Artesian aquifers.

Exact solution to the problem of unsteady drawdown in a leaky artesian aquifer due to a constant discharge nonpenetrating well is presented. Finiteness of the well radius and aquifer anisotropy are considered in formulating the problem. Solution is derived on the assumption that the flux entering the pumped well is uniformly distributed over the plane circular bottom of the well. The aquifer is considered to be finite in thickness, but of infinite lateral extent. The flow of ground water is assumed to be governed by Jacob's model of linear leakage. Laplace transfromation technique is employed in the theoretical development. The drawdown function is numerically integrated in terms of dimensionless parameters of the flow system and the results are depicted in graphs.

76:02F-034
GROUNDWATER OF VOYVODINA, ITS QUALITY AND APPLICABILITY FOR IRRIGATION,
Zivkovik, B.
Faculty of Agriculture, Institut za Poljoprivredna Istrazivanja, Novi Sad, Yugoslavia.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 350-357. 1 fig, 1 tab, 9 ref.

Descriptors: Groundwater, Water quality, Dissolved solids, Irrigation water, Saline soil, Salinity, Groundwater management.

On the basis of the results achieved in groundwater investigations and their applicability in Voyvodina the following conclusions can be made: (1) Groundwater in Voyvodina is mostly of poor quality, has a relatively high content of dissolved salts, and should not be used for irrigation; (2) Underground water in the watersheds of the Danube, Tisza and Sava can be used for irrigation due to their good quality; (3) In order to prevent further soil salinization it is necessary to lower the groundwater level to a harmless depth which, due to the natural conditions in Voyvodina, is 200-250 cm; and (4) It is important to provide expert control both over the usage of the groundwater for irrigation and the control of soil salinization.

Section VII

WATER CYCLE

WATER IN SOILS (GROUP 02G)

76:02G-001
COUPLING PHENOMENA IN SATURATED HOMO-IONIC MONTMORILLONITE: I. EXPERIMENTAL,
Elrick, D.E., Smiles, D.E., Baumgartner, N., and Groenevelt, H.
Guelph University, Department of Land Resource Science, Ontario, Canada.
Soil Science Society of America Journal, Vol. 40, No. 4, p 490-491, July-August 1976. 3 fig, 2 ref.

Descriptors: *Clays, *Montmorillonite, *Soil physical properties, *Soil water movement, Pressure, Salts, Sodium chloride, Electrical properties, Electrochemistry, Membranes, Laboratory tests, Soil water, Groundwater, Soil science.

A series of experiments was performed to observe the effects of salt concentration differences across a thin layer of homo-ionic montmorillonite. The water pressure difference, concentration difference, and voltage difference measured with electrodes reversible to the anion were observed as functions of time. A qualitative explanation of the observations was proposed.

76:02G-002
PERCOLATION OF SURFACE-APPLIED WATER IN THE FIELD,
Quisenberry, V.L., and Phillips, R.E.
Kentucky Agricultural Experimental Station, Lexington, Kentucky.
Soil Science Society of America Journal, Vol. 40, No. 4, p 484-489, July-August 1976. 10 fig, 10 ref.

Descriptors: *Percolation, *Soil water movement, *Soils, *Irrigation, Chlorides, Tracers, Unsaturated flow, Groundwater movement, Infiltration, Percolating water, Porosity, Soil moisture, Soil water, Topsoil, Loam, Clay loam, Rainfall, Agriculture.

Percolation of surface-applied water tagged with chloride was studied in Maury silt loam and Huntington silty clay loam under field conditions. Soil samples were taken in small increments to the 90-cm depth several times following application of water. Analyses of chloride content with depth indicated the position of the applied water relative to the initial soil water in the profile. Three percolation studies were conducted on Maury silt loam soil. In the first study, an application of 4.2-cm of water increased the water content to the 60-cm depth within 1 hour following irrigation even though volumetric water averaged 5% below the upperlimit of the water holding capacity through this depth. A second study conducted at a slightly higher initial water content showed that 20% of a 4.2-cm application had penetrated below the 90-cm depth immediately after application and 40% penetrated below this depth within 1 hour. Similar results were measured in Huntington silty clay loam. Simulated rainfall increased the water content significantly to approximately the 15-cm depth in each of three studies. A large percentage of the water passing this depth apparently percolated past the 90-cm depth with very little adsorption of water and chloride between these depths. Location of chloride in the profile and movement of chloride past the 90-cm depth indicated that a large percentage of the applied water percolated past the water initially present with little displacement of the initial water.

76:02G-003
INFLUENCE OF HYSTERESIS ON MOISTURE FLOW IN AN UNDISTURBED SOIL MONOLITH,
Beese, F., and van der Ploeg, R.R.
Goettingen University, Institute of Soil Science and Forest Nutrition, West Germany.
Soil Science Society of America Journal, Vol. 40, No. 4, p 480-484, July-August 1976. 8 fig, 17 ref.

Descriptors: *Soil moisture, *Hysteresis, *Drying, *Wetting, Soils, Podzols, Gray-brown podzolic soils, Physical properties, Lysimeters, Infiltration, Unsaturated flow, Soil properties, Soil water, Diffusion, Soil water movement, Mathematical models, Model studies, Laboratory tests, Sorption, Soil science.

The moisture dynamics of an undisturbed soil monolith were studied during a lysimeter experiment. Daily measurements were made of the soil suction at 10 depths. Also measured daily were the precipitation, the seepage, and the evaporation from the monolith during a 3-year period. For selected periods, a drying (desorption) curve and a wetting (sorption) curve of the soil moisture characteristic were determined from field data. Also, the capillary conductivity was determined with use of daily monolith observations. By using these hydraulic functions, the unsaturated soil moisture flow equation was solved numerically for one-dimensional vertical flow. In order to determine the effect of hysteresis on the suction distribution in the monolith, calculations were performed either with the desorption curve or with the sorption curve without scanning between the curves. Neither of the two curves led to complete agreement between observed and calculated soil suction values; the desorption curve usually gave too high values, and the sorption curve gave too low values.

76:02G-004

RADIATION HAZARD FROM AMERICIUM-BERYLLIUM NEUTRON MOISTURE PROBES.

Gee, G.E., Stiver, J.F., and Borchert, H.R.
North Dakota State University, Department of Soils, Fargo, North Dakota.
Soil Science Society of America Journal, Vol. 40, No. 4, p 492-494, July-August 1976. 3 fig, 1 tab, 4 ref.

Descriptors: *Soil moisture meters, *Nuclear moisture meters, *Hazards, *Radiation, Soil moisture, Radioactivity, Safety, Instrumentation, Equipment, Monitoring, Measurement, Soil science.

Neutron fluxes from shielded neutron moisture probes need to be measured to evaluate total radiation exposure from these instruments. Theoretical considerations suggest that for 100 mCi Am-Be neutron moisture probes the fast neutron flux can be relatively high and contribute significantly to the radiation exposure of probe operators. Measured radiation dose levels at the surface of 100 mCi Am-Be newtron probes manufactured by Troxler Laboratories were found to be as high as 37 m Rem/hour which exceeds reported levels by as much as 38 times. This was believed to be due to nonreporting of fast neutron fluxes. It was mentioned that conventional field use of these probes may present a radiation hazard to operators if the probe is hand carried for periods which exceed three hours per week. It was recommended that the probe be transported to and from sites inside a wooden storage crate and be kept at least 1 m from personnel. Also, to improve the radiation safety factor for on site use, it was recommended that a hand cart be used to transport the probe.

76:02G-005

MEASURING HYDROLOGIC PROPERTIES OF SOIL WITH A DOUBLE-RING INFILTROMETER AND MULTIPLE-DEPTH TENSIOMETERS,

Ahuja, L.R., El-Swaify, S.A., and Rahman, A.
Hawaii University, Department of Agronomy and Soil Science, Honolulu, Hawaii.
Soil Science Society of America Journal, Vol. 40, No. 4, p 494-499, July-August 1976. 10 fig, 1 tab. 5 ref.

Descriptors: *Hydrologic properties, *Soil water movement, *Soil physical properties, *Hawaii, Soil properties, *Infiltration, *Infiltrometers, *Tensiometers, On-site investigations, Forests, Forest watersheds, Soils, Loam, Clay loam, Percolation, Groundwater movement, Water spreading, Soil science, Instrumentation.

A ring infiltrometer with varying width of buffer zone in combination with multiple-depth tensiometers was tested for determining the hydrologic properties of a Typic Dystrandept (Tantalus silty clay loam) soil profile on a forested watershed in Hawaii. With location of one multiple-depth tensiometer at the vertical axis of the axisymmetric flow system and one or more at a given radius outside the inner ring, the vertical and the radial hydraulic gradients could be simultaneously measured. It was thus possible to estimate the lateral flow components and to determine vertical infiltration rates and hydraulic conductivities (at field saturation) of the different soil horizons. Lateral flow decreased with time during infiltration. Under the moist-to-wet conditions of the soil under study, lateral flow was not appreciable. From an inner ring of 30-cm diameter, the lateral flow was practically eliminated when a buffer ring of 90-cm diameter was employed. The effect of lateral flow on the final infiltration rate was negligible even when a buffer ring of 60-cm diameter was used.

76:02G-006
VISCOSITY OF INTERLAYER WATER IN MONTMORILLONITE,
Low, P.F.
Purdue University, Department of Agronomy, Lafayette, Indiana.
Soil Science Society of America Journal, Vol. 40, No. 4, p 500-505, July-August 1976. 4 fig, 1 tab, 30 ref.

Descriptors: *Viscosity, *Permeability, *Clays, *Montmorillonite, *Viscous flow, Flow resistance, Diffusion, Hydraulic conductivity, Porous media, Soils, Soil properties, Physical properties, Analytical techniques, Groundwater movement, Soil science.

The viscosities of water in Na-montmorillonite system at various contents were calculated by different equations using data from experiments conducted by different investigators on; (1) viscous flow of water at different temperatures, (2) self-diffusion of water, and (3) neutron scattering by water. The results were remarkably consistent and showed that the viscosity of the interlayer water is greater than that of bulk water and increases exponentially with decreasing water content. Evidence was also presented to show that the viscosity of this water depends on the b-dimension of the montmorillonite. By combining the data on viscosity with data on hydraulic conductivity, it was possible to determine the permeability of the montmorillonite at different water contents.

76:02G-007
HEAT AND WATER MOVEMENT UNDER SURFACE ROCKS IN A FIELD SOIL: I. THERMAL EFFECTS,
Jury, W.A., and Bellantouni, B.
California University, Department of Soil Science and Agricultural Engineering.
Soil Science Society of America Journal, Vol. 40, No. 4, p 505-509, July-August 1976. 6 fig, 2 tab, 13 ref.

Descriptors: *Soils, *Rocks, *Heat flow, *Soil moisture, Soil water movement, On-site investigations, Model studies, Mathematical models, Thermal conductivity, Water vapor, Mulching, Droughts, Arid lands, Groundwater movement, Soil science.

Results of a field experiment designed to evaluate the effect of surface rocks on soil heat flow were presented. Temperature observations were made by thermocouples at 12 locations under and adjacent to rocks placed over bare soil. Continuous readings were taken for 24- and 48-hour intervals using seven different kinds of rock cover, ranging from large granite slabs to gravel piles, during the time between December 1974 and August 1975. Experimental results consistently showed a non-negligible 24-hour net horizontal heat flow toward the rock at both the 2.5 and 5.0 cm depth. Net vertical heat flow was always downward in the soil under the bare surface but was observed to be either upward or downward in the soil under the rock cover depending on prior conditions. Because water vapor movement in moist soil is generally in the same direction as heat flow, it was suggested that surface rock cover may be a mechanism for water collection in arid climates. A simulation model was constructed to describe two-dimensional heat flow in a uniform soil with a rectangular rock on the surface. Using the measured surface temperature as boundary values and a soil thermal conductivity corresponding to the mean daily soil surface temperature, the simulation model adequately reproduced the observed temperatures under and adjacent to the rock.

76:02G-008
HEAT AND WATER MOVEMENT UNDER SURFACE ROCKS IN A FIELD SOIL: II. MOISTURE EFFECTS,
Jury, W.A., and Bellantouni, B.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 4, p 509-513, July-August

1976. 5 fig, 3 tab, 7 ref.

Descriptors: *Soils, *Rocks, *Heat flow, *Soil moisture, Soil water movement, On-site investigations, Laboratory tests, Model studies, Mathematical models, Computer models, Thermal conductivity, Water vapor, Mulching, Droughts, Arid lands, Groundwater movement, Moisture effects.

Results were presented from a field experiment conducted to determine the effect of surface rocks on soil water content change under bare soil. First, stones were placed at intervals over an initially dry field (gravimetric water content = 0.021 g/g) and left for 6 weeks. Subsequent sampling showed a small, but detectable, excess of water stored under the rock compared to adjacent bare soil. Following an irrigation, buried thermal conductivity probes were used to monitor water content changes under and adjacent to surface rocks. After 24 days, the soil under the rock contained significantly more water than did the soil region adjacent to the rock, a finding confirmed by gravimetric sampling. Following this, the stones and probes were relocated for a further 24 days of observation, with similar results obtained. In a separate laboratory experiment using a large sealed soil column with a rock covering part of the surface, it was demonstrated that a significant amount of water moved to the cylinder of soil under the rock from the soil region under the bare surface due to horizontal temperature gradients induced by the rock covering part of the surface. A two-dimensional computer program calculating water vapor movement under thermal gradients was used with measured field temperature boundary conditions to estimate the amount of water vapor movement expected to occur due to a rock cover on the soil surface. Results qualitatively confirmed the observations of the sealed laboratory column experiment.

76:02G-009
FIELD MAPPING SOIL CONDUCTIVITY TO DELINEATE DRYLAND SALINE SEEPS WITH FOUR-ELECTRODE TECHNIQUE,
Halvorson, A.D., and Rhoades, J.D.
Agricultural Research Service, Sidney, Montana.
Soil Science Society of America Journal, Vol. 40, No. 4, p 571-575, July-August 1976. 7 fig, 3 tab, 8 ref.

Descriptors: *Saline soils, *Conductivity, *On-site investigations, Arid lands, Salinity, Measurement, Salts, Groundwater, Seepage, Mapping, Soil water, Soils, Maps, Surveys, Soil science.

Continuing incidence of saline-seep areas in the northern Great Plains dryland soils has created a need for detecting and delineating encroaching saline seeps before plant growth is affected. This paper reported on an evaluation of the four-electrode conductivity technique for field mapping surface and subsurface soil salinity under dryland conditions. Results indicated that the four-electrode conductivity technique can be used successfully to quickly field map surface and subsurface soil salinity boundaries of existing and potential saline-seep areas. This technique also depicted underground flow patterns of a shallow, saline groundwater table. Maps of apparent bulk soil conductivity values were used to locate the position of the recharge area in relation to the discharge (seep) area. While maps of discrete depth interval conductivity values provided more precise information, the time required may not warrant the additional required calculations unless a portable programmable calculator is available. Mapping soil salinity with the four-electrode conductivity technique was easy, rapid, and relatively inexpensive. This technique provides information useful in making management decisions to prevent or alleviate a saline seep or other soil salinity problems.

76:02G-010
A MARKOVIAN STOCHASTIC BASIS FOR THE TRANSPORT OF WATER THROUGH UNSATURATED SOIL,
Bhattacharya, R., Gupta, V., and Sposito, G.
Arizona University, Department of Mathematics, Tucson, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 3, May-June 1976b. 11 ref. OWRT B-046-ARIZS5). 14-34-0001-6057.

Descriptors: *Hydraulic conductivity, *Markov processes, *Unsaturated flow, Stochastic processes, Equations, *Soil water movement, Diffusivity, Soil moisture.

The differential equation that describes the isothermal, isohaline transport of water through a homogeneous, isotropic, unsaturated soil is shown to result from a fundamental stochastic hypothesis; that the trajectory of a water molecule is a non-homogenous Markov process characterized by space- and time-dependent coefficients of drift and diffusion. The demonstration makes possible a new theoretical interpretation of the water diffusivity and the hydraulic conductivity at the molecular level and results in a derivation to the Buckingham-Darcy flux law that does not rely directly on experiment.

76:02G-011
COMPARISON OF DRAINAGE EQUATIONS FOR THE GRAVITY DRAINAGE OF STRATIFIED PROFILES,
Watson, K.K., and Whisler, F.D.
Mississippi State University, Department of Agronomy, Mississippi State, Mississippi.
Soil Science Society of America Journal, Vol. 40, No. 5, p 631-635, September-October 1976. 3 fig, 3 tab, 10 ref.

Descriptors: *Drainage, *Gravity, *Percolation, *Equations, Numerical analysis, Model studies, Mathematical models, Unsaturated flow, Soil water, Soils, Computers, Profiles, Sands, Analytical techniques, Soil science, Agriculture.

The output from a computer-based numerical analysis of the gravity drainage of a sand profile through an underlying impeding layer was used as the data for testing the manner in which algebraic equations are capable of describing the stratified drainage process. The comparisons indicated that no single equation is satisfactory in describing the wide range of nonlinear behavior that occurred with eight cases analyzed. However, when specific coefficients determined from a least squares analysis were used in an equation of the Jackson and Whisler type, satisfactory correspondence was achieved.

76:02G-012
EFFECTS OF LIQUID-PHASE ELECTRICAL CONDUCTIVITY, WATER CONTENT, AND SURFACE CONDUCTIVITY ON BULK SOIL ELECTRICAL CONDUCTIVITY,
Rhoades, J.D., Raats, P.A.C., and Prather, R.J.
Agricultural Research Service, Salinity Laboratory, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 5, p 651-655, September-October 1976. 7 fig, 3 tab, 13 ref.

Descriptors: *Electrical conductivity, *Soils, *Soil water, Model studies, Laboratory tests, Mathematical models, Salinity, Saline soils, Soil properties, Soil types, Soil science.

Recent research has demonstrated that field soil salinity can be inferred from four-electrode soil electrical conductivity if the soil profile is near 'field capacity' and calibration curves, based on saturation extract salinity, are available. To extend the use of this field method to arbitrary water contents, electrical conductivity was studied in the laboratory as a function of water content and in situ soil water conductivity. Undisturbed cores of four soil types were collected using Lucite column inserts, which were tapped for later insertion of electrodes. The cells were equilibrated with waters of a desired conductivity and, using a pressure membrane apparatus, adjusted to a desired water content. Values of soil electrical conductivity were calculated from measured four-electrode resistances and an appropriate cell constant. A relationship was derived using a simple capillary model, which assumes that liquid phase and surface conductivities (via exchangeable cations) behave as resistors in parallel.

76:02G-013
SURFACE SOIL MOISTURE WITHIN A WATERSHED--VARIATIONS, FACTORS INFLUENCING, AND RELATIONSHIP TO SURFACE RUNOFF,
Henninger, D.L., Petersen, G.W., and Engman, E.T.
Pennsylvania State University, University Park, Pennsylvania.
Soil Science Society to America Journal, Vol. 40, No. 5, p 773-776, September-October 1976. 2 fig, 4 tab, 16 ref.

Descriptors: *Soil moisture, *Watersheds (Basins), *Pennsylvania, Surveys, Data processing,, Soils, Soil types, Precipitation (Atmospheric), Runoff, Evaporation, Vegetation effects, Drainage, Moisture meters, Nuclear moisture meters, Soil science.

Surface soil moisture was measured within the upper 15 cm, using neutron-scattering equipment, on six soil series, within a 57.8-ha Pennsylvania watershed during the 19 May to 11 November 1971 period. Surface soil moisture was responsive to individual storm events, showed discernible seasonal trends, and displayed larger fluctuations at higher moisture levels than at lower moisture levels. An analysis of variance showed that well-drained soils had significantly different surface soil moisture levels than the more poorly drained soils. Also, well-drained soils could be grouped into a hydrologic unit distinct from the more surements along parallel transects which were approximately perpendicular to the slope contours, showed high surface soil moisture contents proximal to the stream, indicating that these areas contribute more to surface runoff in a shorter period of time than areas distant from the stream channel. Multiple regression equations, using pan evaporation and surface soil moisture for each soil series, were used to show the relative importance of the internal soil drainage class in predicting surface runoff.

76:02G-014
PREDICTING RUNOFF INITIATION TIMES UNDER FIELD CONDITIONS IN TROPICAL (HAWAII) SOILS,
Ahuja, L.R., Dangler, E.W., and El-Swaify, S A.
Hawaii Universtiy, Department of Agronomy and Soil Science, Honolulu, Hawaii.
Soil Science Society of America Journal, Vol. 40, No. 5, p 777-779, September-October 1976. 1 fig, 1 tab, 10 ref. ARS-USDA 12-14-5001-19, 12-14-5001-40.

Descriptors: *Runoff, *Soil types, *Hawaii, *Simulated rainfall, Rainfall-runoff relationships, Soils, Infiltration, Ponding, Rainfall, Precipitation (Atmospheric), Surface runoff, Hydraulic conductivity.

Runoff initiation times measured during field rain-simulation studies on 10 important Hawaii soils were examined in relation to antecedent soil water status. The experimental data showed considerable scatter, which was due mainly to natural soil variability within a soil series. However, the data exhibited a fairly proportional relationship between runoff initiation time and antecedent soil saturation deficit (final minus initial soil water content), in accordance with a simple Green-Ampt type equation. The results indicated a potential method for estimating erosive portions of rainstorms and subsequent soil loss hazards in relation to varying antecedent soil water contents during different seasons of the year.

76:02G-015
AN ELECTRICAL CONDUCTIVITY PROBE FOR DETERMINING SOIL SALINITY,
Rhoades, J.D., and van Shilfgaarde, J.
Agricultural Research Service, Salinity Laboratory, Riverside, California.
Soil Science Society of America Journal, Vol 40, No. 5, p 647-651, September-October 1976. 4 fig, 2 tab, 7 ref.

Descriptors: *Saline soils, *Electrical conductance, *Instrumentation, *Equipment, Soil properties, Irrigation, Salts, Electrical equipment, Soils, Salinity, Soil science, *Salinity.

An electrical conductivity probe for determining soil salinity was described, including construction details. The probe's utility for measuring soil salinity within discrete soil depth intervals was illustrated with examples. Using the salinity probe, the Barnes method for estimating electrical conductivity profiles was shown to be accurate for soils that are reasonably homogeneous laterally.

76:02G-016
PREDICTION OF EVAPORATION FROM COLUMNS OF SOIL DURING ALTERNATE PERIODS OF WETTING AND DRYING,
Staple, W.J.
Soil Research Institute, Department of Agriculture, Ottawa, Ontario, Canada.
Soil Science Society of America Journal, Vol. 40, No. 5, p 756-761, September-

October 1976. 7 fig, 1 tab, 22 ref.

Descriptors: *Evaporation, *Soils, *Soil properties, Infiltration, Laboratory tests, Model studies, Hydraulic conductivity, Drying, Wetting, Soil moisture, Soil water movement, Loam, Soil water, Soil science.

The analysis was undertaken to test certain approximations in using finite difference methods to compute evaporation and soil water conservation. Analysis of four evaporation experiments showed that water movement in Wood Mountain clay loam was sufficiently repeatable during wetting and drying to permit computation of evaporation losses on the basis of predetermined soil properties. The experiments involved evaporation after the following treatments: (1) infiltration penetrating partway down columns of air-dry soil; (2) infiltration and 7 days' redistribution; (3) treatment (2) plus additional infiltration; and (4) repeated infiltration applied at different stages of initial drying. In computing evaporation, the Richards and Dalton flow equations were used with soil and atmospheric parameters. Temperature gradients in the soil were neglected. Hydraulic conductivity of the surface layers of soil were adjusted empirically to estimate combined liquid and vapor movement and to correct for disruptive effects such as dispersion, air blockage, and swelling near the surface. The independent domain theory was used to estimate the influence of hysteresis on capillary pressures during alternate wetting and drying. Agreement between measured and computed evaporation was satisfactory following infiltration, except when water was added after more than 7 days' evaporation.

76:02G-017

SEEPAGE FROM TRAPEZOIDAL CANAL IN ANISOTROPIC SOIL,

Reddy, A.S., and Basu, U.
Indian Institute of Science, Department of Civil Engineering, Bangalore.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 102, No. IR2, Proceedings Paper 12386, p 349-361, September 1976. 6 fig, 28 ref. 2 append.

Descriptors: *Irrigation, *Seepage, *Canals, Irrigation canal, Permeability, Anisotropy, Homogeneity, Phreatic lines, Hydrology, Hudraulics, Equations, Flow.

An analytical solution which takes into account the general anisotropic behavior of the porous medium was found for the problem of seepage flow from an unlined trapezoidal canal. Since a canal in an anisotropic medium transforms into one with unequal slopes in an equivalent isotropic porous medium, the solution here was concerned with the problem of seepage flow from an unsymmetrical trapezoidal canal. The method of inversion of hodograph was made use of, and expressions for the seepage loss and the locations of the phreatic lines were obtained. Numerical results were presented for the equivalent isotropic flow domain. Using the transformation formulas given, the actual discharge and the locations of phreatic lines in anisotropic medium can be easily obtained for given physical parameters of the actual flow domain. The nonsymmetry of trapezoidal canals of side slopes less than one has considerable influence on the quantity of seepage.

76:02G-018

PREDICTION OF INFILTRATION INTO LAYERED FIELD SOILS IN RELATION TO PROFILE CHARACTERISTICS,

Bruce, R.R., Thomas, A.W., and Whisler, F.D.
Agricultural Research Service, Watkinsville, Georgia.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 4, p 693-698, 703, July-August 1976. 12 fig, 4 tab, 15 ref.

Descriptors: *Infiltration, *Soil profiles, *Soil classification, *Storms, *Soil horizons, *Pressure head, Soil moisture, Hydraulics, Porosity, Numerical analysis, Soil physics, On-site tests, *Forecasting.

An infiltration model based on flow theory was used to examine the effects of nature and extent of soil horizons in profiles of a clayey soil upon infiltration and soil water distribution. It was concluded that the characteristics and thickness of the surface soil horizon which overlies a subsoil of higher clay content and lower saturated hydraulic conductivity determine infiltration and consequent distribution fo soil water during a significant period of a rainfall event. The period may vary from 10 to 40 minutes for high-intensity storms, depending upon initial soil water content, and for a longer period for dry soils and low-intensity storms. The B2 horizon of the soil tested begins to regulate infiltration after 30 to 40 minutes. The duration of these periods assumes insignificant effect hydraulic characteristics. The model adequately described infiltration into a grass covered plot.

76:02G-019
ANALYTICAL SOLUTIONS OF A SIMPLIFIED FLOW EQUATION,
Raats, P.A.C.
Agricultural Research Service, Salinity Laboratory, Riverside, California.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 4, p 683-689, July-August 1976. 6 fig, 35 ref.

Descriptors: *Infiltration, *Soil water movement, *Hydraulic conductivity, *Moisture content, *Analytical techniques, Pressure head, Hydraulics, Soil physics, Model studies, Flow, Capillary action, Equations.

Assuming that the hydraulic conductivity is an exponential function of the pressure head, a simplified flow equation was derived. The influence of hysteresis was ignored. The flow equation contained a constant that can be interpreted as a natural length of the soil and a function that delimits a natural time. Solutions of three special forms of the flow equation were discussed: (1) steady flows from point and line sources and to points and line sinks, (2) steady vertical flow, subject to distributed uptake by plant roots and a water table, and (3) transient redistribution following irrigation. All solutions presented hinge upon the exponential and the pressure head. The relationship was believed to be valid if the range of hydraulic conductivities is small.

76:02G-020
EFFECT OF MICROORGANISMS ON THE SORPTION AND FATE OF SULFUR DIOXIDE AND NITROGEN DIOXIDE IN SOIL,
Ghiorse, W.C., and Alexander, M.
Cornell University, Department of Agronomy, Ithaca, New York.
Journal of Environmental Quality, Vol. 5, No. 3, p 227-230, July-September 1976. 3 fig, 4 tab, 22 ref.

Descriptors: *Sorption, *Nitrification, *Microorganisms, Sulfur compounds.

Sulfur dioxide was rapidly removed from the gas phase in contact with both nonsterile and sterile soil so that viable microorganisms are not directly involved in removal of this pollutant from the atmosphere. Sulfate was formed from the SO2 in nonsterile and sterile soil. About one-fourth of the sulfur from the SO2 introduced was not recovered in inorganic form, but the recovery was quantitative if the soil was first ignited to destroy organic matter. Nitrogen dioxide was also readily lost from the gas phase in contact with nonsterile and sterile soil, and both nitrite and nitrate were generated. The role of microorganisms in the fate of this pollutant is in the conversion of the nitrite to nitrate.

76:02G-021
EFFECT OF DISSOLVED OXYGEN ON REDOX POTENTIAL AND NITRATE REMOVAL IN FLOODED SWAMP,
Engler, R.M., Antie, D.A., and Patrick, W.H. Jr.
Department of the Army, Corps of Engineers, Waterways Experiment Station, Environmental Effects Laboratory, Vicksburg, Mississippi.
Journal of Environmental Quality, Vol. 5, No. 3, p 230-235, July-September 1976. 6 fig, 2 tab, 14 ref.

Descriptors: *Nitrates, *Dissolved oxygen, *Louisiana, *Floodwater, Coastal marshes, Laboratory tests, Soil investigations.

The O2 depletion rates, NO3(-) loss, and the effects of added O2 on NO3(-)

disappearance and redox potential in four flooded or intermittently flooded soils from the swamp and coastal marshes of Louisiana were quantitatively characterized in a laboratory study. The NO3(-) added either to the shallow floodwater or mixed with the soil in a suspension rapidly disappeared. Eighty to ninety parts per million NO3(-) was lost from the soil suspensions in 1 to 4 days and from the floodwater over a soil in 10 to 20 days. No NO3(-) was lost from floodwater separated from the soils. Oxygen depletion in the soil suspensions occurred in 15 minutes to 4 hours. Redox potential curves exhibited a characteristic inflection after O2 disappearance in all soils studied. Nitrate disappearance did not appear to be inhibited by as much as 16 ppm O2 dissolved in the soil suspensions because the O2 was rapidly consumed.

76:02G-022
THE EFFECTS OF TEMPERATURE AND SOIL WATER ON CONVERSION OF DDT TO DDE IN SOIL,
Guenzi, W.D., and Beard, W.E.
United States Department of Agriculture, Agricultural Research Service, Western Region, P.O. Box E., Fort Collins, Colorado.
Journal of Environmental Quality, Vol. 5, No. 3, p 243-246, July-September 1976. 2 fig, 2 tab, 13 ref.

Descriptors: *Pesticides, *Insecticides, *Chemical degradation, *Persistence, *Microbial degradation, Soil water, Soil investigations, Temperature.

A laboratory study was conducted to determine the rates of DDT degradation and DDE formation in soil. Degradation rates increased with higher temperatures and in the presence of water. Of the DDT mixed with Raber silty clay loam, 82.1, 74.5, 53.2, and 38.3% was recovered as DDT and 6.7, 12.5, 21.6, and 34.8% as DDE after 140 days incubation at 30, 40, 50, and 60C, respectively. A comparison of DDE formation in sterile and nonsterile soil showed that 84% of the conversion was due to a chemical process at 30C, and 91% at 60C. In sterile systems at 30C, rates of DDE formation were similar in submerged soil and soil at 1/3 bar suction, and both were much higher than in air-dried soil.

76:02G-023
INFLUENCE OF CROP MANAGEMENT PRACTICES ON NUTRIENT MOVEMENT BELOW THE ROOT ZONE IN NEBRASKA SOILS,
Muir, J., Boyce, J.S., Seim, E.C., Mosher, P.N., and Deibert, E.J.
Nebraska Agricultural Experiment Station, Lincoln, Nebraska.
Journal of Environmental Quality, Vol. 5, No. 3, p 255-259, July-September, 1976. 9 fig, 12 ref.

Descriptors: *Nitrogen, *Potassium, *Root zone, *Leaching, Irrigation effects, Nebraska, Soil investigations, Alfalfa, Corn.

Deep profile sampling under different water and crop management systems revealed limited movement of N and none of P from the rooting profile of non irrigated Nebraska soils. Leaching of N to the water table was apparent in most irrigated soils located on valley positions and in sandy soils of the uplands. Alfalfa with its deep rooting system, was noted to be an effective scavenger of inorganic N that may have accumulated under prior crops.

76:02G-024
EVALUATION OF A CAPILLARY BUNDLE MODEL FOR DESCRIBING SOLUTE DISPERSION IN AGGREGATED SOILS,
Rao, R.S.C., Green, R.E., Ahuja, L.R., and Davidson, J.M.
Florida University, Department of Soil Science, Gainesville, Florida.
Soil Science Society of America Journal, Vol. 40, No. 6, p 815-820, November-December 1976. 4 fig, 2 tab, 21 ref.

Descriptors: Model studies, Hawaii, Soil water, Soil water movement, Pores, Pore water, Soils, Soil investigations.

A simple capillary bundle model was evaluated for describing solute dispersion in two well-aggregated soils of Hawaii. The model enables the use of pore-water velocity distribution rather than an average pore-water velocity. The pore-size distribution was calculated from the soil water characteristic data.

The position and relative shape of the break-through curves calculated by the capillary bundle model was dependent more on the pore-water velocity distribution than on dispersion owing to mixing within a pore. The predicted break-through curves were extremely skewed and did not describe the measured curves. The mixing of solute between adjacent flow paths, a process not accounted for in the model, apparently resulted in failure of the model. A measure of pore accessibility and interconnectedness of pore sequences is essential for quantitative description of the influence of soil pore geometry on solute dispersion.

76:02G-025
SIMULATION OF PROFILE WATER STORAGE AS RELATED TO SOIL HYDRAULIC PROPERTIES,
Hillel, D., and Van Bavel, C.H.M.
Texas A and M University, Texas Agricultural Experiment Station, Department of Soil and Crop Science, College Station, Texas.
Soil Science Society of America Journal, Vol. 40, No. 6, p 807-815, November-December 1976. 12 fig, 1 tab, 18 ref.

Descriptors: Numerical analysis, Simulation analysis, Soil properties, Soil investigations, Model studies, Soil moisture, Soil water, Soil water movement, Infiltration, Water conservation, Evaporation.

A previously published numerical model of soil-water dynamics was used to simulate the separate and combined processes of infiltration, drainage, and evaporation, as determined by hydraulic properties. Three hypothetical soils were compared: sand, loam, and clay. Typical soil moisture characteristic functions were assigned to each, and the respective hydraulic conductivity functions were calculated. Uniform profiles of these soils were then subjected to various sequences of rainstorms and dry periods. The sandy soil provided the least evaporation and the most rapid downward flow. This resulted in the most effective storage under a relatively dry regime. The situation was reversed in the case of the clay soil, which stored the most water under a relatively wet regime, while the loam exhibited intermediate behavior. Some consequences of this pattern affecting arid zone ecology are discussed.

76:02G-026
EXPERIMENTAL STUDY OF WETTING FRONT INSTABILITY INDUCED BY SUDDEN CHANGE OF PRESSURE GRADIENT,
White, I., Colombera, P.M., and Philip, J.R.
Commonwealth Scientific and Industrial Research Organization, Division of Environmental Mechanics, P.O. Box 821, Canberra City, 2601 Australian Capital Territory, Australia.
Soil Science Society of America Journal, Vol. 40, No. 6, p 824-829, November-December 1976. 8 fig, 2 tab, 10 ref.

Descriptors: *Soil water, Soil water movement, Infiltration, Soil investigations, Soil properties, Soil moisture.

Twenty-two experiments were performed on stability of infiltration flows in Hele-Shaw cells. Flows were perturbed by suddenly changing G, the pressure gradient behind the wetting front, from a definite negative to a definite positive value. Three methods were used; (i) increasing air-pressure ahead of the front, (ii) employing a nonwetting stratum, and (iii) suddenly stopping liquid supply and preventing air-entry. Glycerol and silicone, with contrasting properties, were used as the infiltrating liquids. The experiments confirmed the theory of Philip: immediately G was made positive, all flows became unstable, and the observed wavelengths of fingering agreed closely with those predicted by the theory. A modification of the theory to take account of the geometry of the microscopic air-liquid interface predicts wavelengths in soil about twice as large as does the original theory. A preliminary experiment on infiltration of water in a coarse sand confirmed the theory qualitatively, but the observed wavelength was twice that predicted theoretically. In a preliminary experiment on infiltration in a fine sand, perturbation failed to produce instability. This divergence from theory is attributed to deviations from the delta-function model on which the theory is based. Further experimental and theoretical work is needed.

76:02G-027
EFFECT OF PH AND COMPLEX FORMATION ON MERCURY (II) ADSORPTION BY BENTONITE,
Newton, D.W., Ellis, R. Jr., and Paulsen, G.M.
Kansas State University, Department of Agronomy, Manhattan, Kansas.
Journal of Enviromental Quality, Vol. 5, No. 3, p 251-254, July-September 1976.
3 fig, 3 tab, 14 ref.

Descriptors: *Heavy metals, *Clays, *Chlorides, *Salts, *Mercury, Aquatic environment, Aquatic population.

Reactions of Hg with bentonite clay were studied to determine behavior of the metal in aquatic ecosystems. Mercury (II) adsorption by bentonite as a function of pH and complex formation was investigated using a radioisotopic technique. Maximum Hg(II) adsorption in 0.01M $Ca(NO_3)_2$ systems occurred in the pH range 4.5-5.5. Varying the $Ca(NO_3)_2$ concentration only slightly influenced adsorption or the pH of maximum adsorption. Chloride ions sharply reduced Hg(II) adsorption, especially at low pH's. At pH 6 or lower, increasing $CaCl_2$ levels were required to decrease adsorption at pH 7. At a given Cl(-) concentration, maximum observed Hg(II) adsorption occurred near the calculated pH where HgClOH occurred as a transition complex between $HgCl_2$ and $Hg(OH)_2$. Chloride salts were more effective desorbers of Hg(II) than was 0.01M $Ca(NO_3)_2$ or various o.01N acids. HCL (0.01N) removed the most adsorbed Hg(II).

76:02G-028
SIMULATION OF ROOT-ZONE WATER AND DEEP SEEPAGE TO A WATER TABLE,
King, T.G., and Lambert, J.R.
Connell/Metcalf and Eddy, Coral Gables, Florida.
Presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers, December 15-18, 1975, Chicago, Illinois. 12 p., 5 fig, 2 ref.

Descriptors: *Model studies, *Root zone, Moisture tension, Soil water, *Soil water movement, *Seepage, *Water table, Evapotranspiration, *Computer models, Simulation analysis.

The primary objective was to develop a computer model that would simulate the quantity and movement of water in the deep seepage region, i.e., between the root zone and the water table. Effort was also directed towards simulating evapotranspiration and the movement of the water table. The model has been structured so that it may readily be modified to other locations where basic meteorological records and soil data are available.

76:02G-029
MODELING INFILTRATION AND REDISTRIBUTION OF SOIL WATER DURING INTERMITTENT APPLICATION,
James, L.G., and Larson, C.L.
Minnesota University, Department of Agricultural Engineering, St. Paul, Minnesota.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 482-488, May-June 1976. 7 fig, 4 tab,22 ref.

Descriptors: *Infiltration, *Infiltration rates, *Soil physics, *Unsaturated flow, *Soil water movement, *Unsteady flow, Soils, Porous media, Equations, Soil properties, Mathematical models, Laboratory tests, Computers.

A model that used relatively simple and reasonably accurately measured parameter equations was used to represent infiltration and redistribution of soil water during intermittent water applications. Application of the model was limited to short time periods since evapotranspiration was neglected and only impervious and air-soil interface type lower boundaries to the soil zone were considered. The soil was required to be homogeneous and to have distinct wetting front. Laboratory data were collected and compared with the model predictions. The model was found to predict satisfactorily the runoff quantities and timing, the volume of water stored in the soil, and the soil moisture profiles including the position of the wetting front. The model over-predicted the infiltration rate when the application rate exceeded tht infiltration capacity of the soil.

76:02G-030
RAPID DETERMINATION OF UNSATURATED HYDRAULIC CONDUCTIVITY IN TILLED AND UNTILLED LOESS SOIL,
Ehlers, W.
Gottingen University, Institut fur Pflanzenbau und Pflanzenzuctung, von-Siebold-Str. 8, 34 Gottingen, West Germany.
Soil Science Society of America Journal, Vol. 40, No. 6, p 837-840, November-December 1976. 3 fig, 4 tab, 12 ref.

Descriptors: *Hydraulic conductivity, *Diffusivity, Evaporation, Porosity, Soil properties, Soil investigations.

A rapid method recently developed for determining moisture diffusivity and unsaturated hydraulic conductivity in undisturbed soil cores was employed to calculate the hydraulic functions of the upper layers of tilled and untilled loess soil. The results obtained with the new method compare well with results obtained by a field method. Diffusivity functions as influenced by tillage and depth were significantly different. Conductivities were highest in the 20-30-cm layer of untilled and were lowest in the same layer of tilled soil. The number of replicates necessary to evaluate the hydraulic functions with arbitrarily specified precision was calculated. For the soil under study, five to nine samples are needed, when upper and lower limits of the 95% confidence interval of diffusivity means are defined not to be different more than by a factor of three.

76:02G-031
POTASSIUM STATUS OF SOME ALLUVIAL SOILS IN KENTUCKY,
Rasnake, M., and Thomas, G.W.
Kentucky University, Department of Agronomy, Lexington, Kentucky.
Soil Science Society of America Journal, Vol. 40, No. 6, p 883-886, November-December 1976. 7 fig, 3 tab, 21 ref.

Descriptors: *Kentucky, *Potassium, *Bermudagrass, Soil chemistry, Soil chemical properties, Soils, Soil investigations.

Six alluvial soils from Kentucky were intensively cropped to 'Midland' bermudagrass to determine K availabiltiy in each soil. Potassium removal by the bermudagrass was compared to exchangeable K, to labile K estimated from Beckett quantity/intensity plots and to Gapon coefficients before and after cropping. Exchangeable K was not a good measure of uptake (r = 0.61 not significant), but labile K determined on soils before cropping and the Gapon coefficient after cropping gave highly significant linear correlations with K removed by bermudagrass. Exchangeable K after cropping changed an average of only 23 ppm K in the soils, but availability of K to plants was lowered drastically in all soils. This study shows that exchangeable K is an insensitive measurement of K availability to plants. Exchangeable K is a useable measurement only because wide ranges are used in determining classes of availability in soil testing.

76:02G-032
COUPLING PHENOMENA IN SATURATED HOMO-IONIC MONTMORILLONITE: II. THEORETICAL,
Groenevelt, P.H., and Elrick, D.E.
Guelph University, Department of Land Resource Science, Guelph, Ontario, Canada.
Soil Science Society of America Journal, Vol. 40, No. 6, p 820-823, November-December 1976. 11 ref.

Descriptors: *Clays, Soil water, Soil water movement, Model studies, Thermodynamics, Salts, Saturated soils.

A theory is presented for the formulation of flux equations which describe the transport of water, salt, and electric charge through clays. This theory is based on thermodynamics principles. Model considerations lead to analytical expressions for the transport coefficients. These model calculations are based on electric double layer theory and produce a symmetric matrix of coefficients. The difference with former theories and model calculations is that the analysis is for electrodes which are reversible to the anions instead of the cations. The impact of this difference on the magnitude of some of the coefficients and on some of the physico-chemical responses of the system is formidable.

76:02G-033
AN IMPROVED TECHNIQUE FOR MEASURING SOIL PH,
Mubarak, A., and Olsen, R.A.
Montana State University, Agricultural Experiment Station, Bozeman, Montana.
Soil Science Society of America Journal, Vol. 40, No. 6, p 880-882, November-December 1976. 2 fig, 3 tab, 17 ref.

Descriptors: Soil properties, Soil investigations, Soil chemistry, Soil chemical properties, Laboratory tests.

Soil solution is obtained by immiscible displacement using centrifugation in the presence of an excess of carbon tetrachloride. A combination glass electrode is then introduced into the soil solution which is floating on top of the carbon tetrachloride. By keeping the system closed, changes in pH induced by loss or gain of carbon dioxide are avoided. No water need be added to a naturally occurring soil so changes in pH induced by the dilution effect and/or the salt effect are obviated. There is no contact between reference electrode and soil particles so there is considered to be no junction error involved in the measurement. The technique is simple and reasonably convenient; the readings are stable and apparently reliable.

76:02G-034
SOIL AIR PRESSURE EFFECTS ON ROUTE AND RATE OF INFILTRATION,
Linden, D.R., and Dixon, R.M.
United States Department of Agriculture, Minnesota University, Department of Soil Science, Saint Paul, Minnesota.
Soil Science Society of America Journal, Vol. 40, No. 6, p 963-965, November-December 1976. 3 fig, 7 ref.

Descriptors: *Infiltration, Soil water, Soil moisture, Soil properties, Soil investigations, Soils.

One centimeter of 0.1% methylene blue solution was infiltrated into soil with various constant soil air pressures beneath the wetting surface to measure flow into and through soil macropores. Flow was increasingly impeded as soil air pressure increased from 0 to 5 mbars. Infiltration rates during the first 3 min of wetting were decreased by an order of magnitude with 5 mbars of air-back pressure.

76:02G-035
MASS TRANSFER STUDIES IN SORBING POROUS MEDIA I. ANALYTICAL SOLUTIONS,
van Genuchten, M. Th., and Wierenga, P.J.
Princeton University, Department of Agronomy, Princeton, New Jersey.
Soil Science Society of America Journal, Vol. 40, No. 4, p 473-480, July-August 1976. 6 fig, 26 ref.

Descriptors: *Mass transfer, *Porous media, *Adsorption, Analytical techniques, Soils, Soil properties, Soil chemistry, Soil water movement.

An analytical solution is presented for the movement of chemicals through a sorbing porous medium with lateral or intra-aggregate diffusion. The liquid phase in the porous medium is divided into mobile and immobile regions. Diffusional transfer between the two liquid regions is assumed to be proportional to the concentration difference between the mobile and immobile liquids. Sorption processes in both the dynamic and stagnant regions of the medium are assumed to be instantaneous and the adsorption isotherm is assumed to be linear. The analytical model derived here describes the extensive tailing observed during flow through an unsaturated, aggregated sorbing medium and explains the often observed early breakthrough of chemicals in the effluent.

76:02G-036
DETERMINATION OF SOIL-WATER DIFFUSIVITY FOR ANISOTROPIC STRATIFIED SOILS,
Sawhney, B.L., Parlange, J.-Y., and Turner, N.C.

The Connecticut Agricultural Experiment Station, Department of Soil Chemistry, New Haven, Connecticut.
Soil Science Society of America Journal, Vol. 40, No. 1, p 7-9, January-February 1976. 3 fig, 10 ref.

Descriptors: *Diffusivity, *Infiltration, Stratification, Soils, Soil investigations, Soil properties.

The unsaturated soil-water diffusivity of an anisotropic soil can be described by a second-order tensor. In the particular case of a stratified soil, the diffusivity tensor is defined by the two values of the diffusivity in the principal directions, one normal and one parallel to the soil layer. The standard method of Bruce and Klute then requires the use of two soil columns, one for each direction, to define the diffusivity tensor. The present method makes use of a two-dimensional similarity solution first derived for an isotropic medium and extended here to a stratified soil. It is then possible to obtain the diffusivity tensor of the stratified soil from one experiment only. As an illustration of the method, the diffusivity tensor of a mica layer is measured and the result is used to analyze infiltration from a finite trench.

76:02G-037
COMPARISONS OF CALCULATED AND MEASURED CAPILLARY POTENTIALS FROM LINE SOURCES,
Thomas, A.W., Duke, H.R., Zachmann, D.W., and Kruse, E.G.
United States Department of Agriculture, Agricultural Engineering, Watkinsville, Georgia.
Soil Science Society of America Journal, Vol. 40, No. 1, p 10-14, January-February 1976. 4 fig, 2 tab, 11 ref.

Descriptors: *Infiltration, *Subsurface irrigation, Irrigation, Capillary action, Hydraulic conductivity, Model studies, Soil moisture.

This paper is a sequel to D.W. Zachmann and A.W. Thomas' (1973) development of equations describing steady infiltration from line sources. Calculated distributions of capillary potentials are compared with those measured in a soil bin designed to model the water distribution from a subsurface irrigation system. Limitations of the steady-state equations for predicting capillary potentials are given. A procedure for selecting lateral depth and spacing to attain a given matric flux potential is also given.

76:02G-038
BULK DENSITY, SATURATION WATER CONTENT AND RATE OF WETTING OF SOIL AGGREGATES,
Gumbs, F.A., and Warkentin, B.P.
West Indies University, Department of Soil Science, Trinidad, West Indies.
Soil Science Society of America Journal, Vol. 40, No. 1, p 28-33, January-February 1976. 4 fig, 5 tab, 12 ref.

Descriptors: *Bulk density, *Soil properties, Soils, Soil investigations, Porosity, Evaporation, Soil aggregates, Soil moisture, Sorption, Infiltration, Clays, Pores.

Bulk density, degree of saturation, volume increase on wetting, and rate of wetting were measured for aggregated and clods of Ormstown silty clay loam (Humaquept) of sizes from 5 cm to 0.036 cm diameter. Bulk density increased with a decrease in diameter. For 2.2-mm to 0.36-mm diameter aggregates this increase was due to a surface area effect, i.e., loss in porosity as a result of subdividing larger aggregates. Both surface area effects and increased porosity from root channels and fissures were required to explain the increase for clods between 5 and 1 cm diameter. An evaporation and a sorption technique are described and used to estimate the water content of aggregates at saturation, i.e., the intra-aggregate water content. The evaporation technique gave reliable results at specific rates of evaporation, but the sorption technique was not as useful. Clods and aggregates of the soil and of pumice samples did not fully saturate; entrapped air accounted for 25 to 27% of the total pore volume. Aggregates of 1 and 2.2 mm diameter and clods of 1.0 and 5.0 cm diameter took about 1, 1.7, 45, and 1,000 seconds, respectively, to saturate. This rapid wetting would minimize differences in potential between inter-and intra-aggregate water during infiltration.

76:02G-039
SOIL-HEAT FLUX DETERMINATION: TEMPERATURE GRADIENT METHOD WITH COMPUTED THERMAL CONDUCTIVITIES,
Kimball, B.A., Jackson, R.D., Nakayama, F.S., Idso, S.B., and Reginato, R.J.
United States Water Conservation Laboratory, 4331 East Brasdway, Phoenix, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 1, p 25-28, January-February 1976. 1 fig, 2 tab, 13 ref.

Descriptors: *Thermal conductivity, *Heat flow, Soils, Soil investigations, Soil properties.

Surface soil-heat fluxes were determined for 6 days in a field of Avondale loam using the null-alignment method, the combination method, and four variations of the temperature gradient method with thermal conductivities computed from the DeVries' theory for particular reference depths. For all methods, calorimetry was used to obtain the surface flux from the flux determined for the reference depth. There was 10% or less difference between the null-alignment, combination, and temperature gradient methods for a 20-cm reference depth. However, the difference with respect to the null-alignment method increased to 35% for a 5-cm reference depth when DeVries' theory was closely followed. This difference was reduced to 3% when a modified air shape factor was used in the computations and all vapor movement was ignored. We concluded that the temperature gradient method with conductivities computed from DeVries' theory could be reliably used with a 20-cm reference depth, but that a "calibration" of the theory for a particuulr soil should be obtained before the method is used with a 5-cm reference depth.

76:02G-040
COMPARISON OF FIELD-MEASURED AND CALCULATED SOIL-HEAT FLUXES,
Kimball, B.A., Jackson, R.D., Reginato, F.S., Nakayama, F.S., and Idso, S.B.
United States Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 1, p 18-25, January-February 1976. 5 fig, 1 tab, 32 ref.

Descriptors: *Soil temperature, *Thermal conductivity, *Heat flow, Soils, Soil investigations, Water vapor, Temperature, Soil water movement.

Soil-heat fluxes calculated using DeVries' theory (1958, 1963) were compared with those experimentally determined in a field of Avondale loam at Phoenix, Arizona, on 6 days representing different seasons of the year. A fair agreement between measured and computed fluxes was obtained only after modifying the air shape factor curve and ignoring heat transfer due to water vapor movement. The omission of the latter implied that heat transfer by pure conduction was most important and that thermal and isothermal vapor fluxes exactly cancelled during the day and were insignificant at night. "Measured" thermal conductivities were also determined from the ratio of the measured heat fluxes to the corresponding temperature gradient for those times when it was unlikely that isothermal vapor movement was significant. The lack of a temperature dependence in these data, as well as the flux comparisons, strongly indicate that the theory over estimated thermal vapor movement. These data plus others in the literature indicate that an individual "calibration" of the theory for a particular soil is required before reliable predication of soil-heat flux can be obtained.

76:[illegible]G-041
SOIL MOISTURE FLUX AND EVAPOTRANSPIRATION DETERMINED FROM SOIL HYDRAULIC PROPERTIES IN A CHAPPARAL STAND,
Scholl, D.G.
Rocky Mountain Forest and Range Experiment Station, 5423 Federal Building, 517 Gold Avenue Southwest, Albuquerque, New Mexico.
Soil Science Society of America Journal, Vol. 40, No. 1, p 14-18, January-February 1976. 3 fig, 1 tab, 11 ref.

Descriptors: *Soil moisture, *Soils, *Soil properties, *Evapotranspiration, Model studies, Water balance, Overland flow, Soil water movement, Hydraulic conductivity.

Measurements of rainfall, overland flow, soil moisture, and hydraulic properties were obtained from a sloping plot in a chaparral stand. The moisture characteristic and dynamic conductivity were determined from core samples of several soil layers to a depth of 420 cm. A water balance model requiring the above parameters and a Darcian moisture flux analysis was used to predict drainage below the root zone and loss by evapotranspiration. Daily results of the water balance were summarized during 2 water years. Predicted values agreed well with values measured on a nearby watershed during both years--the first an unusually dry year, the second unusually wet.

76:02G-042
METHYLATION OF MERCURY IN AGRICULTURAL SOILS,
Rogers, R.D.
United States Environmental Protection Agency, Office of Research and Development, Soil Microbiology, Las Vegas, Nevada.
Journal of Environmental Quality, Vol. 5, No. 4, p 454-458, October-December 1976. 7 tab, 24 ref.

Descriptors: Agricultural soils, Mercury, Soil texture, Soil moisture, Soil temperature, Soils, Soil investigations.

Methylation of applied divalent mercury ion was found to occur in agricultural soils. The production of methylmercury was affected by soil texture, soil moisture content, soil temperature, concentration of the ionic mercury amendment, and time. Methylation was directly proportional to clay content, moisture content, temperature, and mercury concentration. After an initial build-up of methylmercury in the soil, there appeared to be a mechanism that decreased the methylmercury content with increasing time.

76:02G-043
NITRATE-NITROGEN MOVEMENT THROUGH SOIL AS AFFECTED BY SOIL PROFILE CHARACTERISTICS,
Devitt, D., Letey, J., Lund, L.J., and Blair, J.W.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California.
Journal of Environmental Quality, Vol. 5, No. 3, p 283-288, July-September 1976. 4 fig, 2 tab, 14 ref.

Descriptors: *Nitrogen, Soil investigations, Manganese, Chlorides, Denitrification, Leaching, Irrigation practices.

The contribution of agricultural practices to pollution of ground and surface waters by nitrogen is not completely known. Six tile systems installed on commercial farms with differing soil profile characteristics were selected for investigation. Soil solution samples were extracted from 61-, 91-, 122-, and 183-cm depths and analyzed for nitrate-nitrogen, manganese, and chloride concentrations, and electrical conductivity. Redox potential measurements were made at 91- and 183-cm depths. Tensiometers were installed at 61-, 91-, and 122-cm depths to measure hydraulic gradients. Tile effluent samples were also collected and analyzed. Data on redox potential, manganese concentrations, and nitrate-nitrogen concentration and movement were dependent on water movement and amounts of nitrate available for leaching. Irrigation management to provide low leaching fraction resulted in relatively higher nitrate-nitrogen concentration in the tile effluent but smaller amounts of total nitrate lost as compared to irrigation management for high leaching fractions. Redox potentials and the chloride to nitrate-nitrogen ratios indicated that subsurface layers of high clay content promote denitrification. With one exception, a smaller fraction of the applied nitrogen was lost in the tile effluent from profiles containing layers of high clay content as compared to the coarse-textured profiles.

76:02G-044
INFLUENCE OF PESTICIDES ON DENITRIFICATION IN SOIL AND WITH AN ISOLATED BACTERIUM,
Bollag, J.-M., and Henninger, N.M.
Pennsylvania State University, Department of Soil Microbiology, University Park, Pennsylvania.
Journal of Environmental Quality, Vol. 5, No. 1, p 15-18, January-March 1976.
2 fig, 3 tab, 8 ref.

Descriptors: *Pesticides, *Denitrification, Insecticide, Inhibition, Fungicides, Herbicides, Anaerobic conditions.

Various pesticides were tested for their influence on the denitrification process in soil and on an isolated denitrifying bacterium. In soil the denitrifying activity was essentially inhibited by the fungicides captan, maneb, nabam, and to a lesser extent by the herbicide 2,4-D. In pure culture studies with a bacterium whose end product in denitrification was nitrous oxide, the fungicides also caused strong inhibition of the respiratory nitrate reduction process; the insecticide carbaryl, the phenylurea herbicides, 2,4-D and propham (isopropyl carbanilate) also functioned as inhibitors, but to a lesser extent. It was of special interest to observe that the inhibition by certain perticides influenced the formation rate of nitrite and sometimes prevented the reduction of accumulated nitrite during incubation under anaerobic conditions.

76:02G-045
FATE OF FERTILIZER NITROGEN IN A FLOODED RICE SOIL,
Patrick, W.H. Jr., and Reddy, K.R.
Louisiana State University, Laboratory of Flooded Soils and Sediments, Department of Agronomy, Louisiana Experiment Station, Baton Rouge, Louisiana.
Soil Science Society of America Journal, Vol. 40, No. 5, p 678-681, September-October 1976. 3 fig, 4 tab, 11 ref.

Descriptors: *Rice, *Fertilization, Nitrogen, Nutrients, Soil investigations, Flood irrigation, Irrigation effects, Irrigation.

In order to improve the efficiency of fertilizer N utilization by rice, it is important to know what happens to N applied to the soil. Field experiments utilizing N15-enriched ammonium sulfate were carried out to determine the fate of fertilizer N (100 kg N/ha) applied to Crowley silt loam soil. The distribution of fertilizer N in the plant-soil system at harvest time was determined using 2.32 sq m plots. The distribution of fertilizer N in the plant-soil-floodwater system at six times during the growing season was measured in smaller plots (0.28 sq m). The results from the larger plots showed that fertilizer N recovered in the grain ranged from 30.9 to 37.3 kg N/ha depending on the method of application. Recovery of fertilizer N in the straw ranged from 18.2 to 24.2 kg N/ha. A considerable portion of fertilizer N (24.2 to 27.1 kg N/ha) remained in the soil (including roots) after cropping. Total recovery of the 100 kg/ha addition of labelled fertilizer N in the soil-plant system was 75.0 to 85.6 kg N/ha for the different methods of N application examined. Experiments using the smaller 0.28 sq m plots showed rapid uptake of fertilizer N immediately after application, with no apparent further uptake after about 3 weeks. Soil N was the major and perhaps sole source of N for the plant during the last part of the growing season.

76:02G-046
NITRIFICATION-DENITRIFICATION REACTIONS IN FLOODED SOILS AND WATER BOTTOMS: DEPENDENCE ON OXYGEN SUPPLY AND AMMONIUM DIFFUSION,
Patrick, W.H. Jr., and Reddy, K.R.
Louisiana State University, Louisiana Agricultural Experiment Station, Department of Agronomy, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol. 5, No. 4, p 469-472, October-December 1976. 5 fig, 10 ref.

Descriptors: *Nitrogen, *Denitrification, Oxygen, Anaerobic, Aerobic, Soils, Soil investigations, Nitrate.

Ammonium nitrogen in a flooded soil or water bottom exposed to oxygen from the water column undergoes sequential nitrification and denitrification. Oxygen moving through the overlying water column causes the development of an aerobic surface layer of soil or sediment. Ammonium in this aerobic surface layer is nitrified and the resulting ammonium concentration gradient across the aerobic layer and the underlying anaerobic layer causes ammonium in the anaerobic layer to diffuse upward into the aerobic layer where it also undergoes nitrififation. Nitrate produced in the aerobic layer then diffuses downward into the anaerobic layer where it is denitrified to N_2 and N_2O. Nitrate derived from ammonium nitrogen in the aerobic layer appears as an intermediate product in the nitrification-denitrification reaction. A laboratory experiment utilizing N-15 as a tracer showed that approximately one-half of the nitrogen involved in the nitrification-denitrification process was ammonium originally present in the surface aerobic soil or water bottom layer with the remainder diffusing up from the underlying anaerobic layer. Where oxygen was absent or limiting, nitrification either did not occur or occurred at a lower rate, resulting in a reduced amount of nitrate available for the denitrification process.

76:02G-047
NITRATE LEAKAGE FROM SOILS DIFFERING IN TEXTURE AND NITROGEN LOAD,
Avnimelech, Y., and Raveh, J.
Israel Institute of Technology, Soils and Fertilizers Laboratory, Technion, Haifa, Israel.
Journal of Environmental Quality, Vol. 5, No. 1, p 79-82, January-March 1976. 1 fig, 1 tab, 10 ref.

Descriptors: *Nitrogen, *Nitrate, *Chloride, Soil profile, Soil texture, Clay soils, Leaching, Denitrification, Soil investigations, Soils.

Nitrogen and chloride distribution in soil profiles underlying plots differing in the nitrogen load and soil type were studied in the coastal plain of Israel. Nitrate leakage was defined as the product of the average nitrate concentration in subsoil solution times the annual water recharge. A large portion of the excessive nitrogen (nitrogen load minus nitrogen uptake by the removal crop) was not recovered.. This portion is high for clay soils and for plots receiving high nitrogen dressings. Changes in the NO_3/Cl ratio along the soil profile coincided with nitrate removal. This data supports the hypothesis that nitrate removal is mainly due to denitrification in the top layer of the soil.

76:02G-048
THE INFLUENCE OF APPLIED PHOSPHORUS, MANURE, OR LIME ON UPTAKE OF LEAD FROM SOIL,
Zimdahl, R.L., and Foster, J.M.
Colorado State University, Department of Botony and Plant Pathology, Fort Collins, Colorado.
Journal of Environmental Quality, Vol. 5, No. 1, p 31-34, January-March 1976. 3 tab, 17 ref.

Descriptors: *Lead, *Corn, *Phosphorus, Lime, Heavy metals, Soil investigations, Translocation, Soils.

Studies of the uptake of lead from soil by corn have shown that soil applications of phosphorus ($Ca(H_2PO_4)_2\ H_2O$) decrease uptake, but translocation was affected and at higher lead levels. Lead uptake decreased when cow manure was added to attain a total organic content of 6%, but there was no effect of additional manure. Liming did not have a consistent effect on uptake, but lead translocation appeared to decrease with liming. The addition of phosphorus was not an agronomically feasible way to reduce the effects of lead contamination, but additions of manure and lime offered promise of reducing lead uptake.

76:02G-049
USE OF THE GREEN-AMPT EQUATION WITH VARIABLE CONDUCTIVITY,
Ahuja, L.R., and Tsuji, G.Y.
Hawaii University, Department of Agronomy and Soil Science, Honolulu, Hawaii.
Soil Science Society of America Journal, Vol. 40, No. 4, p 619-622, July-August 1976. 2 fig, 13 ref.

Descriptors: Infiltration, Hydraulic conductivity, Soil water, Soil water movement, Hawaii.

A comparison with Philip's two-term equation, derived from a series solution involving t(1/2), indicates that the hydraulic conductivity in the Green-Ampt equation of vertical infiltration varies with time when the soil water content of the transmission zone is assumed to be constant. Use of the Green-Ampt equation with a continuously variable conductivity or a piecewise application of the equation as an extension of Philip's two-term equation resulted in improved prediction of infiltration in two Hawaii soils. Both these forms of application require three parameters, hydraulic conductivity, sorptivity, and constant A, which have well-established physical meaning.

76:02G-050

TRANSIENT MOVEMENT OF WATER AND SOLUTES IN UNSATURATED SOIL SYSTEMS, PHASE II,
Evans, D.D. Sammis, T.W., and Warrick, A.W.
Arizona University, Department of Hydrology and Water Resources.
Available from the National Technical Information Service, Springfield, Virginia as PB-261 348, Price codes: A03 in paper copy, A01 in microfiche. Completion Report, September 1976. 40 p, 14 fig, 9 tab, 12 ref. OWRT B-040-ARIZ(1). 14-31-0001-4059.

Descriptors: *Unsaturated flow, *Tritium, *Soil water movement, *Arizona, *Solutes, Deep percolation, *Seepage, Methodology, Salts, Aquifers, Water quality, Pollutant identification, Darcy's Law.

This project yielded results on the movement of water and solutes from beneath the root zone to a water table aquifer in an irrigated area near Phoenix, Arizona. Three methods were explored for estimating deep seepage rates. They were: (1) measurement of the hydraulic conductivities and gradients and by Darcy's equation calculating the seepage rate; (2) measurement of the temperature profile and calculating the seepage rate from the shape of the profile curve; and (3) measurement of the tritium concentration of the soil water and relating it to the history of the tritium concentration of precipitation. The different methods were used at one site where a deep well was drilled to obtain samples, but the temperature-profile method was tried at other locations. Errors are involved in all of the methods so results differed. At the principal site of the study the Darcian velocity estimate (volume of flow per unit area per unit time) ranged from 9 to 38 cm/yr, while the actual velocity estimate (pore velocity) ranged from 57 to 130 cm/yr. The results from other sites indicated an even lower rate of seepage. The solute concentration of the soil water was higher than the aquifer water but, at the one site, the effect of salts in the seepage water should not significantly alter the quality of the aquifer water.

76:02G-051

INFLUENCE OF CATION CONTENT ON THE BIOLOGICAL ACTIVITY OF FENSULFOTHION IN PLAINFIELD SAND,
Harris, C.R., and Bowman, B.T.
Research Institute, Agriculture Canada, University Sub Post Office, London, Ontario, Canada.
Soil Science Society of America Journal, Vol. 40, No. 3, p 385-389, May-June 1976. 2 fig, 1 tab, 39 ref.

Descriptors: *Cations, *Cation adsorption, *Insecticides, Soils, Soil investigations.

A study was conducted to assess the influence of cations on the biological activity of the organophosphorus insecticide, fensulfothion in soil. Bioassays were done using first stage crickets as test insects and a Plainfield sand without and amended with various concentrations of reagent chloride salts of NH(4+), K(+), Ca(2+), Fe(3+), and Al(3+). The toxicity of fensulfothion decreased with increasing cation content, with the effect being most pronounced with trivalent >divalent > monovalent cations. Results of the bioactivity study paralleled those of an earlier adsorption study on fensulfothion-cation montmorillonite suspensions.

76:02G-052

ERROR PROPAGATION IN DETERMINING HYDRAULIC CONDUCTIVITIES FROM SUCCESSIVE WATER CONTENT AND PRESSURE HEAD PROFILES,

Fluhler, H., Ardakani, M.S., and Stolzy, L.H.
California University, Department of Soil Physics, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 6, p 830-836, November-December 1976. 7 fig, 14 ref.

Descriptors: *Hydraulic conductivity, Darcy's Law, Soil water, Soil water movement, Monte Carlo method, Soil investigations.

The flux of water in unsaturated soils can be determined indirectly by using Darcy's Law. The critical part of this approach is the determination of the hydraulic conductivity at a given depth and time. In this paper the relative errors of hydraulic conductivities determined from a transient drainage field experiment are analyzed. Knowing the errors of this method would be useful in planning future experiments. It allows putting limitations on the conclusions to be drawn from such experiments and it further allows re-examination of already published field data. In the wet range of the conductivity function errors are 20-30% of the k-value. In the range where k-values are small, the relative errors may be > 100%. Errors stemming from tensiometer readings are significant when the hydraulic gradient is < 0.3 mbar . cm(-1). During the early stage of the transient drainage experiment these errors are always considerable and are more important than other errors. On the other hand, the errors in the measured water content changes are dominant when drainage is slowed down due to desaturation of the soil.

76:02G-053
PICLORAM DEGRADATION IN SOILS AS INFLUENCED BY SOIL WATER CONTENT AND TEMPERATURE,
Guenzi, W.D., and Beard, W.E.
United States Department of Agriculture, Department of Soil Science.
Journal of Environmental Quality, Vol. 5, No. 2, p 189-192, April-June 1976.
2 fig, 5 tab, 16 ref.

Descriptors: *Pesticides, *Herbicides, Laboratory tests, Temperature, Soil investigations, Soils, Field capacity, Pesticide residues, Microbial degradation.

A laboratory experiment was designed to determine the effect of temperature and alternating incubations at field capacity and during drying periods on the degradation of picloram in five soils. Picloram was added at a rate of 10 ppm, and degradation was measured by (C-14) O2 evolution resulting from the cleavage of the labeled carboxyl carbon. Picloram degraded very little at 5C and increased only slightly up to 25C. Three soils were highest in degradation rates at 30C while two soils were highest at 50C. Picloram degradation rates during 20-day incubation periods at field capacity, interrupted with 16-day drying cycles, varied among soils and decreased after each successive drying cycle at 30 and 50C, except for one soil at 50C. The degradation rate decreased gradually as water content decreased from field capacity (approximately 0.33 bar) to 15 bars tension, and ceased after the soils were air dried.

76:02G-054
DEGRADATION OF A NONIONIC SURFACTANT IN SOILS AND PEAT,
Valoras, N., Letey, J., Martin, J.P, and Osborn, J.
California University, Department of Soil Physics, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 1, p 60-63, January-February 1976. 3 fig, 4 tab, 7 ref.

Descriptors: *Surfactants, Soil water movement, Soils, Soil investigations, Soil properties, Peat, Adsorption, Soil moisture, Organic matter, Water pollution, Water quality.

Nonionic surfactants are used to improve water movement into water-repellent soils. The effective longevity of treatment and potential water pollution are affected by surfactant degradation. Degradation of C-14-labeled Soil Penetrant 3685, a nonionic surfactant, was measured in incubation studies in the laboratory. Three soils and one peat, numerous surfactant concentrations, and two soil-moisture levels were used as experimental variables. Plots of degradation percentage versus time produced "S" type curves. Increasing the concentration increased the lag period prior to most rapid degradation. The most rapid and highest percentageof degradation were generally associated with soil materials having the lowest adsorptive capacity for the surfactant. From about 75 to 85% of the C-14 was evolved as (C-14) O2 in 1 year for the most favorable conditions for degradation. Degradation rate was decreased by decreasing the soil-moisture content. Degradation of soil organic matter was not greatly affected by surfactant applications--< about 10,000 ppm, but progressively decreased with higher surfactant concentrations.

76:02G-055
SIMULTANEOUS TRANSPORT OF NITRATE AND GASEOUS DENITRIFICATION PRODUCTS IN SOIL,
Rolston, D.E., and Marino, M.A.
California University, Department of Land, Air, and Water Resources, Davis, California.
Soil Science Society of America Journal, Vol. 40, No. 6, p 860-865, November-December 1976. 5 fig, 2 tab, 17 ref.

Descriptors: Fertilizer, Fertilization, Nitrates, Denitrification, Soil properties, Soil investigations, Soil water, Soil water movement, Leaching.

A pulse of NO3(-) fertilizer tagged with N-15 was applied to 100 cm long Yolo loam (Typic xerorthents) topsoil and subsoil columns maintained uniformly unsaturated at soil-water pressure heads between 20- and 140- cm of water at soil-water fluxes between 1.0 and 0.1 cm day(-1). Nitrate, molecular nitrogen, and nitrous oxide from the applied fertilizer were measured as a function of soil depth and time until the NO3(-) pulse eluted from the column. An analytical solution describing the transport and transformation of NO3(-) was used to determine values for the first-order denitrification rate constants within the columns. A numerical solution of the coupled equations for transport and transformation of NO3(-) and diffusion of the gaseous denitrification products was compared with measured N2 and N2O concentration profiles within columns. The gaseous concentration profiles were very much dependent upon values of the denitrification rate constant and the soil gaseous diffusion coefficient. Values of the soil gaseous diffusion coefficient, more than an order of magnitude smaller than those values measured in the upper part of the column, were required to approximately fit the numerical solution to the measured gas concentration profiles.

76:02G-056
AMMONIUM DIFFUSION AS A FACTOR IN NITROGEN LOSS FROM FLOODED SOILS,
Reddy, K.R., Patrick, W.H. Jr., and Phillips, R.E.
Louisiana State University, Department of Agronomy, Baton Rouge, Louisiana.
Soil Science Society of America Journal, Vol. 40, No. 4, p 528-533, July-August 1976. 6 fig, 2 tab, 36 ref.

Descriptors: *Nitrogen, *Leaching, Nitrification, Denitrification, Soil investigations, Ammonium compounds, Anaerobic conditions, Aerobic conditions.

The role of NH4(+)-N diffusion in a flooded soil on nitrogen (N) loss through the nitrification-denitrification process was investigated under laboratory conditions. The distribution of applied NH4(+)-N in both the aerobic and anaerobic soil layers of a flooded soil was experimentally determined and compared with the values obtained from theoretical equations. The total loss of NH4(+)-N from the flooded soil system (15cm depth) by nitrification-denitrification was equivalent to 12.43 g N/sq m for a 120-day incubation period when the initial concentration of NH4(+)-N was 44.84 g N/sq m. Diffusion of NH4(+)-N from the anaerobic soil layer to the aerobic soil layer accounted for more than 50% (7.16 g N/sq m) of the total NH4(+)-N loss with the remainder being lost from NH4(+)-N originally present in the aerobic layer. The NH4(+)-N that diffused upward into the aerobic soil layer was nitrified to NO3(-)-N, which readily diffused back down into the anaerobic soil layer and was subsequently denitrified.

76:02G-057
SAMPLING THE UNSATURATED ZONE OF IRRIGATED LANDS FOR RELIABLE ESTIMATES OF NITRATE CONCENTRATIONS,
Rible, J.M., Nash, P.A., Pratt, P.F., and Lund, L.J.
California University, Department of Soil Science, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 4, p 566-570, July-August

1976. 5 fig, 5 tab, 9 ref.

Descriptors: *Nitrate, *Nitrogen, Soils, Soil properties, Soil investigations.

Data from a study of 56 field sites were used to examine the variability of nitrate-nitrogen concentrations in the unsaturated zone underneath the root zone. The specific data were nitrate-nitrogen concentrations in soil water in samples taken at 0.9-m intervals from the 4.5- to 11.9-m depth from four holes per site. Analyses of variance of these data provided estimates of variances that were used to predict the depth sampling interval and the number of holes required for means to be within the confidence limits of 10, 20, and 30%. Calculations were based on sampling intervals of 0.9, 0.6, and 0.3 m providing 9, 13, and 26 samples per hole, respectively. Relationships developed between number of sites, number of holes required, sampling interval, and confidence limits were used to test selected sampling plans for degree of precision in comparison with the actual sampling procedure. A cost analysis of the field study indicated that it would cost three to four times more than the field study to use a sampling plan which would reasonably ensure that 75% of the sites' true means fall within 20% of the measured means at a confidence level of 95%.

76:02G-058

EVALUATION OF THE PARAMETERS OF SOIL PHOSPHORUS AVAILABILITY FACTORS IN PREDICTING YIELD RESPONSE AND PHOSPHORUS UPTAKE,

Dalal, R.C., and Hallsworth, E.G.
New England University, Department of Agronomy and Soil Science, Armidale, New South Wales, Australia.
Soil Science Society of America Journal, Vol. 40, No. 4, p 541-546, July-August 1976. 1 fig, 5 tab, 37 ref.

Descriptors: *Phosphorus, Nutrients, Crop production, Crop response, Wheat.

The importance of quantity, intensity, capacity, and rate factors of soil P availability to account quantitatively for the variation in P uptake and wheat grain yield in pot and field experiments was studied. Among the parameters of the quantity factor, L value was found to be highly correlated with P uptake at 35 and 150 days after planting (maturity) when all the soils were considered. However, the carbonate P was found to be the best parameter of the quantity factor when the soils containing high amounts of hematite/goethite were excluded. The parameters of the intensity factor were significantly correlated with P uptake at the later stage (150 days). The rate factor, as measured by AER was better correlated with P uptake at 35 days than with P uptake at 150 days after planting. The quantity factor as measured by the carbonate P accounted for 75 and 93% of the variation in P uptake and grain yield, respectively. The capacity factor, Mb when combined with the quantity factor accounted for more of the variation in p uptake (150 days) from 75 to 86%. The intensity and the rate factors had a smaller effect.

76:02G-059

CHANGES IN THE PHYSICAL PROPERTIES OF SOIL CLAYS DUE TO PRECIPITATED ALUMINUM AND IRON HYDROXIDES: II. COLLOIDAL INTERACTIONS IN THE ABSENCE OF DRYING,

El-Swaify, S.A.
Hawaii University, Department of Soil Science, Honolulu, Hawaii.
Soil Science Society of America Journal, Vol. 40, No. 4, p 516-520,July-August 1976. 6 fig, 13 ref.

Descriptors: *Clays, *Flocculation, Soils, Soil properties, Soil investigations, Soil chemistry, Soil chemical properties.

Colloidal stability diagrams were constructed for suspensions of an illite, a kaolinite, and a mixture of the two into which $Al(OH)3$ and $Fe()H)3$ were precipitated. These diagrams covered a pH range form 2.5 to 12.5 and electrolyte concentrations up to the flocculation value. It was revealed, in accordance with expected interactions of colloids with widely different isoelectric points, that the colloidal stability of each mixture was dependent on the charge balance between its individual constituents. Therefore, as long as a system has not encountered a drying cycle, hydroxides may provide favorable (flocculating) or non-favorable (colloidally stable) effects on soil structure depending on hydroxassociated. Generally, the two hydroxides provided equal enhancement of clay colloidal stability above their isoelectric points. However, $Al(OH)_3$ was more active in inducing clay flocculation and charge reversal at low pH values.

76:02G-060

UPTAKE OF CADMIUM BY SOYBEANS AS INFLUENCED BY SOIL CATION EXCHANGE CAPACITY, PH, AND AVAILABLE PHOSPHORUS,

Miller, J.E., Hassett, J.J., and Koeppe, D.E.
Argonne National Laboratory, Argonne, Illinois.
Journal of Environmental Quality, Vol. 5, No. 2, p 157-160, April-June 1976.
1 fig, 5 tab, 21 ref.

Descriptors: *Cadmium, Cation exchange, Phosphorus, Greenhouses, Heavy metals.

The accumulation of cadmium and its affect on vegetative growth of soybeans in soils with a range in cation exchange capacity (CEC), pH and available phosphorus (P) were investigated in greenhouse experiments. Cadmium uptake decreased as soil pH and CEC increased, while increasing available soil P was related to increased Cd accumulation. Cadmium extracted from the soil by Bray P1 reagent, Bray P2 reagent, 2N $MgCl_2$, and 0.1N EDTA was significantly correlated with plant Cd concentrations. The growth of the soybean shoots was generally depressed when tissue concentrations reached 3-5 micro g Cd/g dry weight. Cadmium uptake by soybeans was correlated with the ratio of added Cd to the Cd sorptive capacity of soil.

76:02G-061

NITRITE DECOMPOSITION IN FLOODED SOIL UNDER DIFFERENT PH AND REDOX POTENTIAL CONDITIONS,

Van Cleemput, O., Patrick, W.H. Jr., and McIlhenny, R.C.
Louisiana State University, Louisiana Agricultural Experiment Station, Department of Agronomy, Baton Rouge, Louisiana.
Soil Science Society of America Journal, Vol. 40, No. 1, p 55-60, January-February 1976. 4 fig, 3 tab, 32 ref.

Descriptors: Soils, Soil investigations, Soil properties, Soil chemistry, Nitrites, Sterilant, Soil sterilants.

Nitrite decomposition products were studied in a flooded soil suspension maintained under different pH and redox potential conditions. The effect of a sterilant, $HgCl_2$, on nitrite breakdown was also investigated. Soil suspensions were incubated for several days with the pH maintained at 4.5, 6, and 8 and the redox potential maintained at 0 and +200 mV. Nitrite was then added to the suspensions and the decomposition products were determined by mass spectrometry. Under acid conditions signigicant amounts of N_2 and nitrogen oxide gases (N_2O, NO) were formed in both the moderately reduced (+200 mV) and reduced (0 mV) suspensions. At higher pH's the nitrite reduction rate was slightly less and the amounts of nitrogen oxide gases formed were considerably less with N_2 being the major product. The chemical sterilant decreased the conversion of nitrite to N_2 and markedly increased the formation of NO. The significant production of NO under acid conditions both with and without the sterilant, suggests the likelihood of self-decomposition of nitrous acid as a major mechanism of nitrite loss.

76:02G-062

RELEASE OF CADMIUM FROM CLAYS AND PLANT UPTAKE OF CADMIUM FROM SOIL AS AFFECTED BY POTASSIUM AND CALCIUM AMENDMENTS,

Haghiri, F.
Ohio Agricultural Research and Development Center, and the Ohio State University, Wooster, Ohio.
Journal of Environmental Quality, Vol. 5, No. 4, p 395-397, October-December 1976. 2 tab, 11 ref.

Descriptors: *Cadmium, *Potassium, Clays, Calcium, Kaolinite, Illite, Soybeans, Heavy metals, Soil amendments.

The effects of percent K and/or Ca saturation on the release of Cd from Cd-treated H-clays (kaolinite and illite) and on the Cd availability to plants from Cd-treated Canfield silt loam soil were determined. The concentration of Cd in the dialyzates from both kaolinite and illite clays increased as the percent Ca or K saturation of the clays in the suspension decreased. The release of Cd from both clays was greater in the presence of Ca than K. In a separate experiment, the concentration of Cd in soybean shoots (Glycine max L. Merr.) "Corsoy" decreased with increasing percent Ca or K saturation of the soil. The results indicated that Cd uptake by soybean shoots could be impaired to a great extent by K application.

76:02G-063

SOLUBILITY AND SOLUBILITY PRODUCT OF DICALCIUM PHOSPHATE DIHYDRATE IN AQUEOUS SOLUTIONS AND SOIL SOLUTIONS,

Bennett, A.C., and Adams, F.
Auburn University Agricultural Experiment Station, Department of Soils, Auburn, Alabama.
Soil Science Society of America Journal, Vol. 40, No. 1, p 39-42, January-February 1976. 3 tab, 10 ref.

Descriptors: *Phosphates, Soils, Soil investigations, Soil properties, Solubility.

The solubility product (Ca(2+)) of CaHPO4 . 2H2O was determined in several aqueous solutions containing ions common to soil solutions. Extrapolation of analytical Ca and P concentrations to zero ionic strength yielded pK(sp) values ranging from 6.54 to 6.59 and averaging 6.57 for 10 aqueous salt solutions. A method of successive approximation that computed ionic activity was used to determine the pK(sp) for three concentrations of 15 different aqueous salt solutions saturated with CaHPO4 . 2H2O. Calculated pK(sp) values ranged from 6.44 to 6.63; the average was 6.55. Eight soil samples that varied widely in pH and soil-test P were treated with CaHPO4 . 2H2O at rates of 600 to 3,000 ppm P. Soil solutions were displaced, analyzed, and (Ca(2+)) (HPO4(2-)) was calculated. Eight of the 20 samples of soil were considered to be saturated with CaHPO4 . 2H2O because their (Ca(2+)) (HPO4(2-)) values were approximately the same as that for similar aqueous salt solutions. It was concluded that the presence of excess CaHPO4 . 2H2O in soil could be inferred by ion-activity products of displaced soil solutions.

76:02G-064

AMMONIA VOLATILIZATION FROM SURFACE APPLICATIONS OF AMMONIUM COMPOUNDS ON CALCAREOUS SOILS: V. SOIL WATER CONTENT AND METHOD OF NITROGEN APPLICATION,

Fenn, L.B., and Escarzaga, R.
Texas Agricultural Experiment Station, Texas A and M Research Center at El Paso 10601 North Loop Road, El Paso, Texas.
Soil Science Society of America Journal, Vol. 40, No. 4, p 537-541, July-August 1976. 2 fig, 1 tab, 14 ref.

Descriptors: *Nitrogen, Fertilization, Nutrients, Temperature, Ammonia, Ammonium compounds, Calcareous soils, Soil water.

Ammonia-nitrogen losses from soils were dependent on the existence of sufficient water solubilization of the applied NH4-compounds. Laboratory data revealed that NH3 volatilization from (NH4)2SO4 was greatly reduced on soils with 55% water at 12, 22, and 30 degrees C as compared to soils with 30% water. Ammonia-nitrogen losses were the highest at all temperatures and nitrogen application rates when soils contained 13 to 30% soil water. Dry NH4-chemicals did not dissolve in soils with 0 and 8% soil water, therefore, little NH3 was lost. Application of a concentrated (NH4)2SO4 solution to soils with 8% water resulted in near maximum NH3 loss. This same solution, when applied to the surface of an oven dry soil, resulted in lower losses. Application of NH4NO3 to soils with 55% water resulted in lower NH3 losses when compared to soils with 8 to 30% water. Soils with 0% water retained essentially all applied NH4(+)-N whether applied in dry or concentrated liquid form.

76:02G-065

THE INFLUENCE OF CATION EXCHANGE CAPACITY AND DEPTH OF INCORPORATION ON AMMONIA VOLATILIZATION FROM AMMONIUM COMPOUNDS APPLIED TO CALCAREOUS SOILS,

Fenn, L.B., and Kissel, D.E.
Texas A and M Research Center at El Paso, Texas 10601 North Loop Road, El Paso, Texas.
Soil Science Society of America Journal, Vol. 40, No. 3, p 394-398, May-June 1976. 2 fig, 3 tab, 15 ref.

Descriptors: *Cation exchange, *Calcareous soils, Soils, Soil properties, Soil investigations, Soil chemistry, Model studies.

The objective of this study was to determine the influence of soil cation exchange capacity (CEC) and depth of incorporation on NH3-N volatilization from NH4(+)-N compounds applied to calcareous soil. This study was conducted in the laboratory on soils with a wide range of CEC. An increasing CEC resulted in decreasing NH3 losses. Ammonium sulfate produced higher soil pH values and NH3 losses than did NH4NO3. The pH of the soil decreased with increasing NH4NO3 application rates. With NH4NO3, percent NH3(-)N losses increased as the application rates increased. Incorporation of the NH4(+)-compounds into the soil reduced NH3 losses. Increasing depths of NH4(+)-incorproation resulted in reduced NH3 loss. Losses decreased as the CEC of soil increased. The effectiveness of soil depth in reducing NH3 loss was associated with soil water content. Decreasing the soil water increased the effectiveness of soil incorporation for reducing NH3 losses.

76:02G-066
COMMENTS ON NITRATE REDUCTION IN UNSATURATED SOIL,
McLaren, A.D.
California University, Department of Soil Biology, Berkeley, California.
Soil Science Society of America Journal, Vol. 40, No. 5, p 698-699, September-October 1976. 1 fig, 12 ref.

Descriptors: Nitrite, Nitrate, Ions, Soils, Soil investigations, Nitrification.

Cyclic oxidation and reduction of nitrite and nitrate in soil are analyzed in terms of first-and zero-order microbial kinetic reactions, respectively. A reversible reaction step involving these ions can account for a low, but constant concentration of nitrate in an unsaturated field soil for long periods or for considerable depths in a laboratory soil column.

76:02G-067
RADIAL MOVEMENT OF SATURATED ZONE UNDER CONSTANT FLUX: THEORY AND APPLICATION TO THE DETERMINATION OF SOIL-WATER DIFFUSIVITY,
Sawhney, B.L., and Parlange, J.-Y.
Connecticut Agricultural Experiment Station, New Haven, Connecticut.
Soil Science Society of America Journal, Vol. 40, No. 5, p 635-639, September-October 1976. 3 fig, 11 ref.

Descriptors: Soil water, Soil water movement, Diffusivity, Soils, Soil investigations, Soil moisture.

A two-dimensional similarity solution yields the soil-water diffusivity of an unsaturated soil when the soil water content is measured as a function of the distance from the source. When ponding occurs, the positions of the saturated and unsaturated fronts are related to the diffusivity. If the diffusivity can be described with two parameters, it can be predicted from the position of the two fronts alone without measuring the moisture profile. Four experiments with a fine sandy loam at two different flow rates were performed to determine the diffusivity from the position of the two fronts. The moisture profile was then predicted from the measured diffusivity. The predictions are in good agreement with the observations.

76:02G-068
MICROBIAL FORMATION OF VOLATILE SELENIUM COMPOUNDS IN SOIL,
Doran, J.W., and Alexander, M.
Cornell University, Department of Agronomy, Ithaca, New York.
Soil Science Society of America Journal, Vol. 40, No. 5, p 687-690, September-October 1976. 3 fig, 2 tab, 18 ref.

Descriptors: Selinium, Soil, Soil investigations, Microbial formation, Soil chemistry, Soil properties.

Selenium was volatilized from soils amended with elemental Se, selenite, selenate, trimethylselenonium chloride, selenomethionine, and selenocystine and incubated in air or anaerobically. The processes were wholly or largely the result of microbial action. The conversion of selenite and selenate to volatile products was enhanced if soil was amended with organic materials. Indigenous soil Se was also volatilized in the presence of supplemental organic matter. The products were identified by combined gas chromatography-mass spectrometry. Dimethyl selenide was generated from all Se compounds tested when amended soils were incubated in the presence of air. Under anaerobic conditions, dimethyl selenide was produced from the three organic Se compounds and selenate, and a product tentatively identified as hydrogen selenide (H2Se) was evolved from soil receiving elemental Se, selenite, selenate, or selenocystine. Dimethyl diselenide was also formed from selenomethionine in soil incubated in air or anaerobically.

76:02G-069
TILE DRAINAGE IN BEDDED SOIL OR A DRAW,
Fowell, N.L., and Kirkham, D.
Virginia Polytechnical Institute and State University, Department of Agronomy, Blacksburg, Virginia.
Soil Science Society of America Journal, Vol. 40, No. 5, p 625-630, September-October 1976. 5 fig, 1 tab, 24 ref.

Descriptors: Drainage, Drainage effects, Drainage practices, Tile drains, Tile drainage, Furrow irrigation, Darcy's Law, Furrows, Subsurface drains, Subsurface drainage.

The process of shaping flat land by plowing it into a series of ridges separated by parallel dead furrow is called bedding and the ridge-furrow systems are called beds. The furrows are supposed to remove surface water from the ridges, but often do not. The amount of water that can be removed by tile if they are placed under the furrows is computed on the basis of Darcy's Law and potential theory. In the analysis, water-saturated, steady-state conditions and a subsurface barrier on which the drain tile are laid are assumed. For a poorly drained prairie soil, the calculations show that tile (or plastic tubes, etc.) placed 0.35 m below the furrow bottoms and 30 m apart in beds of 2% slope will remove 5 mm of water/day, and that the bed furrows would have to remove an additional 4.52 mm/day to take care of an expected drainage coefficient of 9.52 mm/day. For general use, 28 depth and spacing geometries are analyzed and tabulated from amounts of flow to tile in the beds. For certain geometries, some of the recharge rainfall seeps in and out of the slope before the water seeps down again into the soil. This in and out seepage occurs for small tile depths, and small tile sizes. Flow nets are presented. It is shown that the theory applies to the drainage of a draw.

76:02G-070
ON THE STOCHASTIC FOUNDATIONS OF THE THEORY OF WATER FLOW THROUGH UNSATURATED SOIL,
Bhattacharya, R, Gupta, V., and Sposito, G.
Arizona University, Department of Mathematics, Tucson,Arizona.
Water Resources Research, Vol. 12, No. 3, June 1976. 40 ref. OWRT B-046-Ariz (4). 14-34-0001-6057.

Descriptors: *Hydraulic conductivity, Diffusivity, *Soil water movement, Stochastic processes, *Unsaturated flow, *Markov processes, Equations, Soil moisture.

The parabolic differential equation that describes the isothermal isohaline transport of water through an unsaturated soil is shown to be the mathematically rigorous result of a fundamental stochastic hypothesis: that the trajectory of a water molecule is a nonhomogeneous Markov process characterized by space- and time-dependent coefficients of drift and diffusion. The demonstration is valid in general for heterogeneous anisotropic soils and provides for three principal results in the theory of water flow through unsaturated media: (1) a derivation of the Buckingham-Darcy flux law that does not rely directly on experiment, (2) a new theoretical interpretation of the soil water diffusivity and the hydraulic conductivity in molecular terms, and (3) a proof that the soil water diffusivity for anisotropic soil is a symmetric tensor of the second rank. A dynamic argument at the molecular level is developed to show that the fundamental Markovian hypothesis is physically reasonable in the case of water movement through an unsaturated soil.

76:02G-071
CAPILLARY HYSTERESIS AND THE RELATIONSHIP BETWEEN DRYING AND WETTING CURVES,
Parlange, J.-Y.
Connecticut Agricultural Experiment Station, New Haven, Connecticut.
Water Resources Research, Vol. 12, No. 2, p 224-228, April 1976. 5 fig, 24 ref.

Descriptors: *Hysteresis, *Soil moisture, *Mathematical models, Theoretical analysis, Equations, Wetting, Drying, Pore water, Capillary action, Pores, Groundwater potential, Air-water interfaces, Boundary processes, Saturation, Sands, Silts, Loam, Soils, Microenvironment, Infiltration.

A simple microscopic model predicted the wetting and drying scanning curves from only one boundary of the main hysteresis loop. Comparison with experiments showed that if the shape of the drying scanning curves varies smoothly, then the drying boundary of the loop is indeed sufficient to predict all scanning curves. However, if the shape of the drying curves changes abruptly, the model is still applicable, but the drying boundary yields only the wetting scanning curves, and the wetting boundary yields only the drying scanning curves. For this case the model seems more reliable for predicting the scanning curves than for the application of interpolation techniques between the two boundaries.

76:02G-072
APPROXIMATIONS FOR VERTICAL INFILTRATION RATE PATTERNS,
Smith, R.E.
Agricultural Research Service, Southwest Watershed Research Center, Tucson, Arizona.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 505-509, May-June 1976. 3 fig, 19 ref.

Descriptors: *Infiltration, *Soil physics, *Infiltration rates, *Unsaturated flow, *Soil water movement, Soils, Porous media, Equations, Soil properties, Mathematical models, Unsteady flow, Computer models, Model studies.

The need for description of the time-varying rate of infiltration into soils led to the development of empirical formulas before the physics of fluid flow in porous media provided theoretical tools for analysis of this aspect of unsaturated soil water movement. Selected contributions toward a usable description of the surface-soil infiltration rate for two boundary and initial conditions were reviewed. The approximations ranged from simple formulas to complex models developed from computer analysis of Richards' equation. The tradeoffs in number of parameters and accuracy were discussed for several infiltration models.

76:02G-073
SOIL WATER MODELING I. A GENERALIZED SIMULATOR OF STEADY, TWO-DIMENSIONAL FLOW,
Amerman, C.R.
Agricultural Research Service, North Central Region Watershed Research Center, Columbia, Missouri.
Transactions of the American Society of Agricultural Engineers, Vol.19, No. 3, p 466-470, May-June 1976. 6 fig, 21 ref.

Descriptors: *Soil water, *Model studies, *Computer models, *Soil water movement, Boundaries (Surfaces), Hydraulic conductivity, Pressure head, Numerical analysis, Darcy's Law, Unsaturated flow, Equations, Porous media, Theoretical analysis, Steady flow.

A computational scheme was developed for solving the steady-state, two-dimensional form of Richard's equation using finite differencing. The successive overrelaxation method was used. The computer model developed for implementing the computational scheme was generalized using a technique called subsectioning, which allows application of the model, without internal modification, to a wide range of geometric shapes, hydraulic boundary conditions, and soil distributions. Unsaturated or saturated flow regions or those containing phreatic surfaces may be modeled. The nonlinear nature of Richard's equation was reflected in the overrelaxation coefficient which had a maximum rather than an optimum value. Values higher than maximum caused instability.

76:02G-074
CALCULATING THE UNSATURATED HYDRAULIC CONDUCTIVITY AND DIFFUSIVITY,
Whisler, F. D.
Mississippi State University, Department of Agronomy, State College, Mississippi.
Soil Science Society of America Journal, Vol. 40, No. 1, p 150-151, January-February 1976. 2 fig, 7 ref.

Descriptors: *Unsaturated flow, *Hydraulic conductivity, *Diffusivity, *Moisture content, *Pressure head, Numerical analysis, Equations, Soil water movement, Soil water, Graphical analysis, Methodology, Soil properties.

The methods of R. D. Jackson and R. H. Brooks and A. T. Corey for calculating the unsaturated hydraulic conductivity from water content-pressure head relationships were compared. The corresponding diffusivity relationships can also be evaluated either by a numerical differentiation of the water content-pressure head curves plus the conductivity, or by direct calculation from the differentiation of the Brooks and Corey function. Both methods gave approximately the same results for the hydraulic conductivity relationships. The diffusivity values calculated from the Brooks and Corey functions were lower than those calculated by the numerical method for a Grenada silt loam soil. Both diffusivity relationships gave essentially the same beta values for the W. E. Gardner and M. S. Mayhugh diffusivity-water content function.

76:02G-075
PLANT WATER STRESS CRITERIA FOR IRRIGATION SCHEDULING,
Stegman, E.C., Schiele, L.H., and Baure, A.
North Dakota State University, Department of Agricultural Engineering, Fargo, North Dakota.
Presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers, December 15-18, 1975, Chicago, Illinois. 22 p, 7 fig, 6 tab, 18 ref. ASAE Paper 75-2555.

Descriptors: *Soil water, *Soil moisture, *Soil-water-plant relationships, *Scheduling, Crop response, Plant physiology, Plant tissues, Irrigation, Irrigation effects.

This study was conducted to determine the potential for relating plant water stress development to variables indicative of prevailing soil and atmospheric environments. Given such relationships irrigation scheduling services should be better able to use plant stress oriented criteria for determining when to irrigate. Stress development was evaluated by leaf xylem pressure and stomatal diffusion resistance measurements. Data sets were obtained for 4 to 5 crops at two Irrigation Branch Stations in North Dakota. The two sites provided soil types with differing hydraulic properties and available water holding capacities. Leaf xylem pressure data for each crop-soil combination were correlated by regression procedures with ambient air temperatures and root zone soil moisture content. Subsequent application of these xylem pressure levels as critical limits to each regression model permitted estimation of allowable root zone soil moisture depletion relative to expected ambient air temperatures. This procedure offers a method for interpreting water balance estimates of soil moisture deficit and advance forecasts of daily maximum air temperatures for need of irrigation.

76:02G-076
FIELD AND LABORATORY EVALUATION OF BI-LEVEL DRAINAGE THEORY,
Chu, S.T., and DeBoer, D.W.
South Dakota State University, Department of Agricultural Engineering, Brookings, South Dakota.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 478-481, May-June 1976. 5 fig, 6 tab, 9 ref.

Descriptors: *Drainage systems, *Theoretical analysis, *On-site tests, *Laboratory tests, Water table, Water levels, Hydraulic conductivity, Porosity, Drains, Data collections, Depth, Graphical analysis, Groundwater movement, Aquifers, Viscosity.

Field and laboratory evaluations of a proposed bi-level drainage (system in which drains are at two different depths on an alternating basis) theory were presented. Graphical comparisons were made between the fall of the water table as predicted by theory and as measured both in the field and in a Hele-Shaw model. In both cases the agreement was good, indicating that the theory is an adequate model to describe the water table fall.

76:02G-077
UPWARD WATER MOVEMENT IN FIELD CORES,
Wells, L.G., and Skaggs, R.W.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 275-283, March-April 1976. 12 fig, 3 tab, 29 ref.

Descriptors: *Groundwater movement, *Subsurface irrigation, *Cores, *Model studies, Laboratory tests, Theoretical analysis, Hydraulic properties, Soil properties, Soil profiles, Soil water movement, Design, Water table, Equations, Irrigation, Pressure head, Moisture content, Boundaries (Surface, Tensiometers, Hydraulic gradient, Hysteresis.

Subirrigation experiments were conducted under various initial and boundary conditions using large, undisturbed cores from two field soils. The pressure head distribution and flow volume were measured continuously, and the desorption and imbibition character of the soil water were determined using pressure plates. The effect of air entrapment on water content was determined gravimetrically, while the hydraulic conductivity-pressure head relationship was determined for each soil from transient pressure head measurements during a drainage event. An approximate model was developed to describe vertical water movement during subirrigation. This model as well as the Richards' equation were tested against experimental results from both soils. Substantial variability was evident in both measured soil properties and in water movement phenomena. The approximate subirrigation model provided acceptable agreement with the observations. Consideration of soil stratification generally improved model accuracy. For engineering design the added time and expense of sophisticated models are not justified in comparison to the approximate model. Determination of the total volume of stored water in a profile under specified boundary conditions is essential to predictions of water movement.

76:02G-078
SURFACE RESIDUE, WATER APPLICATION, AND SOIL TEXTURE EFFECTS ON WATER ACCUMULATION,
Unger, P.W.
Agricultural Research Service, Bushland, Texas, and Southwestern Great Plains Research Center, Bushland, Texas.
Soil Science Society of America Journal, Vol. 40, No. 2, p 2980300, March-April 1976. 2 fig, 14 ref.

Descriptors: *Soil water, *Farm management, *Water storage, *Great Plains, *Organic matter, Mulching, Soils, Loam, Clay loam, Evaporation, Precipitation (Atmospheric), Irrigation, Crops, Wheat, Soil properties, Soil science.

Surface residue rates and water application amounts affect evaporation from soil. These factors were evaluated for their effects on water accumulation in a clay loam and a fine sandy loam soil. Surface residue rates ranged from 0 to 12,000 kg/ha and water was added at 0.25, 0.5, 1.0, or 2.0 cm/addition. At low residue rates and water applications, little or no water accumulated in the soils. The amount of water that accumulated in the soils increased as surface residue rates and water applications increased. Results for the two soils were remarkably similar, apparently because the liquid and vapor flow characteristics for the two soils were similar at high water contents, even though their water retention characteristics differed markedly. The results of this laboratory study were discussed with regard to residue management practices for low (dryland) and high (irrigated) residue production systems of the Great Plains.

76:02G-079
VARIABILITY OF HYDRAULIC CONDUCTIVITY IN TWO SUBSURFACE HORIZONS OF TWO SILT LOAM SOILS,
Baker, F.G., and Bouma, J.
Wisconsin University, Department of Soil Science, Madison, Wisconsin.
Soil Science Society of America Journal, Vol. 40, No. 2, p 219-222, March-April 1976. 3 fig, 10 ref. EPA R802874.

Descriptors: *Hydraulic conductivity, *Soils, *Soil properties, *Variability, Loam, Loess, Silts, Subsoil, Soil horizons, Soil investigations, Infiltration, Groundwater, Groundwater potential, Soil moisture, Soil water movement, Soil science.

Hydraulic conductivity was measured in the B22t and B31t horizons of 12 pedons of two soils developed in loess deposits overlying glacial till. Conductivity measurements were made with the crust test technique for unsaturated conditions and with a new related in situ method for saturated conditions. Nonlinear regression yielded simple well-fitting curves. Variability within and between major horizons in these soil series was found to be relatively low. The four horizons in these two silt loam soils had statistically identical hydraulic conductivity characteristics, even though morphological soil structure and soil genesis differed significantly.

76:02G-080
DETERMINING THE HYDRAULIC CONDUCTIVITY OF SOIL CORES BY CENTRIFUGATION,
Alemi, M.H., Nielsen, D.R., and Biggar, J.W.
California University, Department of Land, Air and Water Resources, Davis, California.
Soil Science Society of America Journal, Vol. 40, No. 2, p 212-318, March-April 1976. 5 fig, 2 tab, 15 ref, 1 append.

Descriptors: *Hydraulic conductivity, *Soils, *Centrifugation, *Infiltration, Laboratory tests, Groundwater movement, Permeability, Diffusivity, Conductivity, Hydrologic properties, Soil water, Soil moisture, Moisture content, Soil properties.

Two centrifugal techniques were proposed for determining the hydraulic conductivity of cores of natural soil. Experimental results were presented for one technique in which the change in weight of one end of the sample, previously centrifugated, was measured with a balance. The mathematical equations describing this redistribution process were developed and fitted to the data to ascertain the soil water diffusivity D. The value of the hydraulic conductivity K was obtained from K - bD, where b is also calculated. Calculated values of K agreed with previously published values. The second technique for which a theory was presented but no experimental values were provided depends upon the measurement of the volumetric outflow of water from a soil core when the speed of centrifugation is suddenly increased.

76:02G-081
DRAINAGE SYSTEM EFFECTS ON PHYSICAL PROPERTIES OF A LAKEBED CLAY SOIL,
Hundal, S.S., Schwab, G.O., and Taylor, G.S.
Ohio State University, Department of Agronomy, Columbus, Ohio.
Soil Science Society of America Journal, Vol. 40, No. 2, p 300-305, March-April 1976. 7 fig, 1 tab, 11 ref.

Descriptors: *Drainage effects, *Crop response, *Soil properties, Drainage, Drainage practices, Soils, Soil physical properties, Soil strength, Compressive strength, Soil texture, Pores, Proosity, Land management, Surface drainage, Subsurface drainage, Hydraulic conductivity, Agriculture.

The long-term effects of drainage on physical properties of a lakebed silty clay soil were evaluated 16 years after initiation of a field experiment. The treatments were undrained, surface drainage, subsurface drainage, and a combination of surface and subsurface drainage. Soil conditions were characterized by surface penetration resistance and by unconfined compressive strength, hydraulic conductivity, and pore size distribution in the 0-30 cm depth. Subsurface drainage resulted in greater soil hydraulic conductivity, less unconfined compressive strength, and less surface crust resistance than treatments without subsurface drainage. Subsurface drainage also decreased bulk density and increased the volume of air-filled pores at 0.02 to 1.0-bar suctions, but these effects were of smaller magnitude. An alfalfa-timothy mixture was grown during the period of these measurements. The survival of alfalfa and the total hay yield decreased in the order: combined surface and subsurface drained, surface drained, and undrained treatments.

76:02G-082
VERTICAL FLOW OF AIR AND WATER WITH A FLUX BOUNDARY CONDITION,
McWhorter, D.B.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 259-265, March-April 1976. 3 fig, 1 tab, 7 ref.

Descriptors: *Soil water movement, *Air-water interfaces, *Infiltration, Air, Viscosity, Compressibility, Equations, Darcy's Law, Permeability, Saturation, Density, Pore pressure, Atmospheric pressure, Water pressure, Hydraulic conductivity, Porosity, Boundaries (Surfaces), Soil properties, Continuity equation, Ponding, Approximation method, Graphical methods.

The effects of viscous resistance to air flow in the downward movement of infiltrating water in soil were analyzed. A conceptual model was used in which air was replaced by a hypothetical incompressible fluid with a viscosity equal to that of air. An equation analogous to Darcy's Law was derived which incorporated resistance to flow of both air and water. The flow equation was later transformed to a dimensionless form. An important assumption used in deriving the equation was that the volume flux of the air is everywhere equal to and opposite in direction to that of water. An approximate solution was obtained using Parlange's technique of successive approximation, and the range of applicability for the solution was determined graphically. Numerical examples were presented which indicated that resistance to flow of an incompressible fluid with a viscosity equal to that of air would significantly influence both ponding time and the maximum infiltration rate short of ponding. Apparently the actual time-to-ponding must be between the two extremes predicted by single-phase and two-phase incompressible flow theory.

76:02G-083
HYDRAULIC PROPERTIES OF A POROUS MEDIUM: MEASUREMENT AND EMPIRICAL REPRESENTATION,
Gillham, R.W., Klute, A., and Heermann, D.F.
Waterloo University, Department of Earth Sciences, Ontario, Canada.
Soil Science Society of America Journal, Vol. 40, No. 2, p 203-207, March-April 1976, 6 fig, 3 tab, 16 ref.

Descriptors: *Hydraulic properties, *Soil water, *Hysteresis, *Porous media, Laboratory tests, Soil moisture, Moisture content, Soil water movement, Groundwater movement, Infiltration, Drainage, Evaporation, Soil moisture meters, Hydrostatic pressure, Pressure head, Wetting, Drying, Soils.

The hysteretic water content-pressure head relationship and the hydraulic conductivity-water content relationship for a porous material are needed in the solution of the water flow equation to predict behavior of a given flow system. These hydraulic properties were measured in an unsteady-state manner using gamma ray attenuation for the water content and strain gage pressure transducer tensiometry for the pressure head. Envelope curves and four to six primary wetting and drying scanning curves of the water content-pressure relationship were determined. A convenient method of representation of the scanning curves by an empirical function was developed for use in computer solutions of the water flow equation.

76:02G-084
SPATIAL VARIABILITY OF THE LEACHING CHARACTERISTICS OF A FIELD SOIL,
Bigger, J.W., and Nielson, D.R.
California University, Department of Land, Air and Water Resources, Davis, California.
Water Resources Research, Vol. 12, No. 1, p 78-84, February 1976. 10 fig, 3 tab, 14 ref.

Descriptors: *Spatial distribution, *Leaching, *Soils, *Soil profiles, Salts, Pore water, Solutes, Infiltration, Diffusion, Sampling, Infiltration rates, On-site investigations, Soil water.

Solute distributions within a soil profile during the leaching of water-soluble salts applied to the soil surface were measured at six depths to 182.4 cm within 20 subplots of a 150 hectare field. Estimates of the pore water velocity based upon measures of solute displacement within each subplot and the entire field were found to be logarithmically normally distributed and in agreement with the volumetric measures of water infiltration rates. Such agreement was possible only because it was recognized that the observed values were not normally distributed and their mean values were calculated accordingly. The number of observations required to yield an estimate of the mean pore water velocity within a prescribed accuracy was shown to depend upon the nautre and extent of the spatial variability of the field soil. For the field examined, 100 observations allowed the mean pore water velocity to be estimated within + or - 50 percent of its true value. The functional relation between field-measured values of the apparent diffusion coefficient, also found to be logarithmically normally distributed, and pore water velocity was examined and interpreted in terms of solute distributions likely to be measured at specific sampling sites.

76:02G-085
INFILTRATION ANALYSIS AND PERTURBATION METHODS I. ABSORPTION WITH EXPONENTIAL DIFFUSIVITY,
Babu, D.K.
City College, Department of Mathematics, New York, New York.
Water Resources Research, Vol. 12, No. 1, p 89-93, February 1976. 1 fig, 25 ref.

Descriptors: *Soil moisture, *Infiltration, *Model studies, *Absorption, Mathematical models, Equations, Analytical techniques, Subsurface waters, Diffusion, Soil temperature, Soil physical properties, Soils, Diffusivity.

Simple perturbation methods were employed to analyze the horizontal absorption of moisture in unsaturated soils. The special case treated assumed the diffusivity to be an exponential function of the concentration and the concentration at the boundaries to be constant. The solution emerged as an explicitly determined power series in the Boltzmann variable. The resulting profiles were compared with some others found in the existing literature. A discussion about the relevance and advantages of this type of analysis formed the concluding part of the paper.

76:02G-086
DIFFUSION AND MASS FLOW OF NITRATE-NITROGEN TO PLANT ROOTS,
Phillips, R.E., NaNagara, T., Zartman, R.E., and Leggett, J.E.
Kentucky Agricultural Experiment Station, Department of Agronomy, Lexington, Kentucky.
Agronomy Journal, Vol. 68, No. 1, p 63-68, January-February 1976. 2 fig, 1 tab, 11 ref.

Descriptors: *Soil-water-plant relationships, *Diffusion, *Soil water movement, *Nitrogen, *Nitrates, *Root systems, Transpiration, Nutrient requirements, Model studies, Flow Moisture content, Absorption, Model studies, Path of pollutants, Corn (Field).

A model for estimating nitrate-nitrogen uptake by plant roots is developed and its application discussed. Soil and plant parameters which must be known in order to predict transport by diffusion and mass flow include volumetric soil water content, N03-N concentration in soil solution, porous diffusion coefficient of soil N03-N, average soil water macroscopic velocity at the plant root surface, root radius, transpiration rate and plant root length. A previously reported steady-state model for simultaneous mass flow and diffusion is evaluated with reference to measurement of those parameters. The importance of diffusion to mass flow is great when the ratio of transpiration rate to the constant of proportionality relating flux into the plant to N03-N concentration in soil solution is less than 0.2.

76:02G-087
INFILTRATION INTO INCREASINGLY PERMEABLE SOILS,
Bouwer, H.
Agricultural Research Service, Water Conservation Laboratory, Phoenix, Arizona.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 102, No. IR1, Proceedings Paper 11959, p 127-136, March 1976. 3 fig, 1 tab, 9 ref.

Descriptors: *Drainage, *Infiltration, *Infiltration rates, *Permeability, Soil properties, Soils, Digital computers, Irrigation, Hydraulic conductivity, Equations, Wetting, Depth.

A tabular procedure, based on the Green-Ampt equation, was developed to calculate infiltration into soil that becomes more permeable with depth. The procedure is simple and the results compared favorably with those obtained with a digital computer. The procedure supplements a previous paper which showed how the Green-Ampt equation could be used to calculate infiltration into soil becoming less permeable with depth. The Green-Ampt equation is emerging as a useful, simple, yet theoretically sound infiltration equation. The extension of the equation to soils where the permeability changes with depth should enhance its utility in practical applications, where soils are seldom, if ever, uniform.

76:02G-088
ON THE STOCHASTIC FOUNDATIONS OF THE THEORY OF WATER FLOW THROUGH UNSATURATED SOIL,
Bhattacharya, R., Gupta, V., and Sposito, G.
Arizona University, Department of Mathematics, Tucson, Arizona.
Water Resources Research, Vol. 12, No. 3, June 1976. 40 ref.

Descriptors: *Hydraulic conductivity, Diffusivity, *Soil water movement, Stochastic processes, *Unsaturated flow, *Markov processes, Equations, Soil moisture.

The parabolic differential equation that describes the isothermal isohaline transport of water through an unsaturated soil is shown to be the mathematically rigorous result of a fundamental stochastic hypothesis: that the trajectory of a water molecule is a nonhomogeneous Markov process characterized by space-and-time-dependent coefficients of drift and diffusion. The demonstration is valid in general for heterogeneous anisotropic soils and provides for three principal results in the theory of water flow through unsaturated media: (1) a derivation of the Buckingham-Darcy flux law that does not rely directly on experiment, (2) a new theoretical interpretation of the soil water diffusivity and the hydraulic conductivity in molecular terms, and (3) a proof that the soil is a symmetric tensor of the second rank. A dynamic argument at the molecular level is developed to show that the fundamental Markovian hypothesis is physically reasonable in the case of water movement through an unsaturated soil.

76:02G-089
WETTING FRONT PRESSURE HEAD IN THE INFILTRATION MODEL OF GREEN AND AMPT,
Neuman, S.P.
Arizona University, Department of Hydrology and Water Resources, Tucson, Arizona.
Water Resources Research, Vol. 12, No. 3, p 564-566, June 1976. 22 ref.

Descriptors: *Soil water movement, *Model studies, Mathematical studies, *Infiltration, *Pore pressure, *Pressure head, *Air circulation, Wetting, Water pressure, Seepage, Soil properties, Time, Gravitational water sorption, Unsaturated flow, Equations.

A theoretical expression relating the wetting front pressure head in the infiltration model of Green and Ampt to soil characteristics was derived. This expression was identical to that previously suggested by Bouwer on the basis of an analogy with horizontal flow. It differed from a more complete expression recently proposed by Morel-Seytoux and Khanji in that the effect of air mobility was neglected, the need for determining the functional relationship between the relative permeability of air and water saturation thus being avoided.

76:02G-090
A NEW MODEL FOR PREDICTING THE HYDRAULIC CONDUCTIVITY OF UNSATURATED POROUS MEDIA,
Mualem, Y.
Technion-Israel Institute of Technology, Department of Civil Engineering, Haifa, Israel.
Water Resources Research, Vol. 12, No. 3, p 513-522, June 1976. 4 fig, 3 tab, 34 ref, 3 append. U.S.-ISBF 422.

Descriptors: *Unsaturated flow, *Hydraulic conductivity, *Mathematical models, *Porous media, Moisture content, Pore pressure, Saturation, Theoretical analysis, Soil properties, Homogeneity, Porosity, Capillary conductivity, Soil types, Model studies, Equations, Mathematical studies.

A simple analytic model was proposed which predicts the unsaturated hydraulic conductivity curves by using the moisture content-capillary head curve and the measured value of the hydraulic conductivity at saturation. It was similar to the Childs and Collis-George (1950) model but used a modified assumption concerning the hydraulic conductivity of the pore sequence in order to take into account the effect of the larger pore selection. A computational method was derived for the determination of the residual water content and for the extrapolation of the water content-capillary head curve as measured in a limited range. The proposed model was compared with the existing practical models of Averjanov (1950), Wyllie and Gardner (1958), and Millington and Quirk (1961) on the basis of the measured data of 45 soils. It seemed that the new model is in better agreement with observations.

76:02G-091
ANALYTICAL SOLUTION OF THE EQUATION FOR TRANSPORT OF REACTIVE SOLUTES THROUGH SOILS,
Selim, H.M., and Mansell, R.S.
Florida University, Department of Soil Science, Gainesville, Florida.
Water Resources Research, Vol. 12, No. 3, p 528-532, June 1976. 3 fig, 18 ref. OWRT A-026-FLA(8).

Descriptors: *Soil water movement, *Solutes, *Analytical techniques, *Soil chemistry, *Leachate, *Adsorption, Aqueous solutions, Soils, Steady flow, Infiltration, Unsteady flow, Laboratory tests, Equations, Mathematical studies, Soil surfaces.

Mathematical solutions of the differential equation governing reactive solute transport in a finite soil column were developed for two specific cases: continuous solute input and pulse-type solute input at the soil surface. These solutions incorporated reversible linear adsorption as well as irriversible solute adsorption. The irreversible adsorption was expressed by a sink/source term which either may be a constant or may have a concentration-dependent form. The boundary condition used across the surface was that of the third type, which accounted for advection as well as dispersion. To illustrate the significance of using the proper boundary conditions, comparisons were made with two other mathematical solutions. It was concluded that the solution presented was highly useful for low pore flow velocities. For large pore velocities, all three solutions were in agreement.

76:02G-092
WATER TRANSPORT IN THE SOIL-ROOT SYSTEM: TRANSIENT ANALYSIS,
Molz, F.J.
Auburn University, Department of Civil Engineering, Auburn, Alabama.
Water Resources Research, Vol. 12, No. 4, p 805-808, August 1976. 2 fig, 27 ref.

Descriptors: *Soil water movement, *Root zone, *Root systems, *Equations, Soils, Unsteady flow, Potential flow, Numerical analysis, Hydraulic gradient, Available water, Mathematical models, Theoretical analysis, Boundaries (Surfaces), Xylem, Plant tissues, Hydraulic conductivity, Laboratory tests.

Equations were developed which describe the transient flow of water in a cylindrical soil-root system. The main objective was to calculate water potential distributions in the root cortex as well as in the surrounding soil. Numerical results indicated that there will be small water potential gradients in the soil relative to those in the root in the upper 90% of the water availability range. Contrary to past experiments, theory predicted that appreciable amounts of water should flow from roots to soil when roots well supplied with water are in contact with dry soil. An important implication of the study was that models designed to predict the pattern in which roots extract water from soil will have to consider the rate-limiting aspect of the root tissue.

76:02G-093
THE APPLICATION OF THE OVERBURDEN POTENTIAL THEORY TO SWELLING SOILS,
Towner, G.D.
Agricultural Research Council, Unit of Soil Physics, Cambridge, England.
Water Resources Research, Vol. 12, No. 6, p 1313-1314, December 1976. 2 fig, 8 ref.

Descriptors: *Soil water, *Soils, *Hysteresis, Soil moisture, Moisture content, Physical properties, Pore water, Shrinkage, Mathematical models, Water table, Soil science.

From a consideration of alternative loading paths in the shrinkage diagram of swelling soils, it was shown that hysteresis in the relationship between the voids ratio and the moisture ratio may occur, even though no actual reversals of loading have been allowed nor any irreversible structural changes have taken place. Therefore, it was argued that the application of the overburden potential theory to the analysis of situations, such as water profiles above water tables in vertical soil columns, is questionable. The need for experimental studies was stressed.

76:02G-094
A COMPARISON OF TECHNIQUES FOR SOLVING THE DIFFUSION EQUATION WITH AN EXPONENTIAL DIFFUSIVITY,
Parlange, J.-Y., and Babu, D.K.
Connecticut Agricultural Experiment Station, New Haven, Connecticut.
Water Resources Research, Vol. 12, No. 6, p 1317-1318, December 1976. 8 ref.

Descriptors: *Diffusion, *Diffusivity, *Mathematical studies, Equations, Soil water, Sorption.

A recent solution obtained by Babu when the soil water diffusivity has an exponential behavior was compared with two earlier solutions. It was shown that with a slight modification, Babu's perturbation solution is identical to the iterative solution using Cisler's correction. It was also shown that solutions which optimize the sorptivity and the front position are numerically indistinguishable from either the perturbation or the iterative solution but have, in general, a much simpler analytical form.

76:02G-095
ON SOLVING THE INFILTRATION EQUATION--A COMPARISON OF PERTURBATION AND ITERATIVE TECHNIQUES,
Parlange, J.-Y., and Babu, D.K.
Connecticut Agricultural Experiment Station, New Haven, Connecticut.
Water Resources Research, Vol. 12, No. 6, p 1315-1316, December 1976. 10 ref.

Descriptors: *Infiltration, *Gravity, *Diffusivity, Mathematical models, Analytical techniques, Soils, Equations, Soil water, Moisture content, Soil moisture, Soil water movement, Soil science.

A recent solution obtained by Babu following a perturbation method was compared with an earlier iterative method. It was shown that after improvement, Babu's perturbation solution becomes identical to the iterative solution using Cisler's correction. A simpler solution based on an optimal scheme was also presented.

76:02G-096
ASSESSMENT OF AVAILABLE WATER STORAGE CAPACITY OF SOILS WITH RESTRICTED SUBSOIL PERMEABILITY,
McCown, R.L., Murtha, G.G., and Smith, G.D.
Commonwealth Scientific and Industrial Research Organization, Division of Tropical Crops and Pastures, Townsville, Australia.
Water Resources Research, Vol. 12, No. 6, p 1255-1259, December 1976. 3 fig, 25 ref.

Descriptors: *Storage capacity, *Soil water, *Soil moisture, *Root zone, *Permeability, Soils, Water Storage, Tropical regions, On-site investigations, Sampling, Ponding, Subsoil, Soil water movement, Soil horizons, Soil science.

The pasture production of most of the tropics is largely a function of the water regime. One of the few options for control of the water regime in these environments is choice of site. A site parameter of great importance is the available water storage capacity (AWSC) in the root zone. Although estimation of the AWSC is straight-forward on freely drained soils, it is complicated on poorly drained soils by the inapplicability of the concept of field capacity. The latter soils, however, commonly have a buildup of salts at depth in the profile, presumably due to prevailing leaching conditions. The study reported herein was conducted to test the hypothesis that this salt profile can be used to indicate the depth of wetting under conditions similar to those producing maximum subsoil water recharge in this climate. Twenty sites on mainly texture contrast soils, most with poorly drained subsoils, were examined in detail. A close relationship between the observed depth of wetting and the depth to the salt bulge was found. This relationship, together with the total porosity of the top (wettest) stratum of the B horizon, provides a means of estimating the AWSC of the subsoil.

76:02G-097
HYSTERETICAL MODELS FOR PREDICTION OF THE HYDRAULIC CONDUCTIVITY OF UNSATURATED POROUS MEDIA,
Mualem, Y.
Colorado State University, Engineering Research Center, Fort Collins, Colorado.
Water Resources Research, Vol. 12, No. 6, p 1248-1254, December 1976. 12 fig, 12 ref, 1 append. NSF ENG-7611542.

Descriptors: *Hysteresis, *Hydraulic conductivity, *Model studies, Mathematical models, Moisture content, Capillary conductivity, Porous media, Unsaturated flow, Groundwater, Soil water, Pore pressure, Pore water, Soil science.

A theory which permits a quantitative prediction of the actual phenomena of considerable hysteresis characterizing the hydraulic conductivity-capillary head relationships, and the less significant hydraulic conductivity-moisture content hysteresis, was proposed. The models used to represent capillary hysteresis were extended to permit the prediction of the hydraulic conductivity of unsaturated porous media for any continuous process of imbibition and drainage. The generalized models require the same amount of experimental data as the previous models, with the addition of a measured value of the hydraulic conductivity at a definite point. For an incompleter measured theta (psi) loop, the knowledge of K at the minimum measured value of psi can be used to improve prediction. The dependent domain model suggested by Mualem and Dagan was generalized by adding two functions, KL(psi) and KH(psi). All K(psi) scanning curves were expressed with the aid of KL(psi) and KH(psi) by convenient compact formulation similar to that used to describe the theta (psi) curves. Very good agreement between theory and observations was found. The predicted K(psi) **hysteresis** has all the experimentally observed features. The predicted K(theta) hysteretical loop almost shrinks to a unique curve, though the psi(theta) loop, used as data, is of considerable extent.

76:02G-098
A PERTURBATION SOLUTION FOR A NON-LINEAR DIFFUSION EQUATION,
Liu, P.L.-F.
Cornell University, School of Civil and Environmental Engineering, Ithaca, New York.
Water Resources Research, Vol. 12, No. 6, p 1235-1240, December 1976. 2 fig, 2 tab, 17 ref. NSF ENG76-09421.

Descriptors: *Diffusion, *Soil water, *Mathematical models, Equations, Sorption, Boundaries (Surfaces), Diffusivity, Mathematics, Analytical techniques.

Nonlinear diffusion problems with a constant boundary condition were investigated. The concept of diffusion front was utilized to develop a perturbation solution. Results were presented for two specific diffusivities which are functions of the concentrations. The present technique was shown to be efficient and accurate.

76:02G-099
THE CONCISE FORMULATION OF DIFFUSIVE SORPTION OF WATER IN A DRY SOIL,
Brutsaert, W.
Cornell University, School of Civil and Environmental Engineering, Ithaca, New York.
Water Resources Research, Vol. 12, No. 6, p 1118-1124, December 1976. 1 tab, 38 ref.

Descriptors: *Sorption, *Soil water, *Infiltration, *Model studies, Mathematical models, Soils, Soil moisture, Moisture content, Soil moisture movement, Diffusion, Equations, Diffusivity, Wetting, Mathematical studies, Soil science.

Several formulations for the sorption of water in a dry soil obtained on the basis of approximate solution of the nonlinear diffusion were considered, and their relative merits were investigeted. In addition, new solutions were developed by the application of a simple weighting of the available approximations. In a comparison with one of Philip's exact solutions, it was found that the error involved in all these solutions is, at most, of the order of 3 or 4%; however, Parlange's optimization result and the weighting solutions appear to be accurate to within a few thousandths. The sorptivity and the position of the wetting front can be expressed consisely as functions of soil physical parameters by applying either the two-parameter exponential diffusivity of Gardner and Mayhugh or the three-parameter power function diffusivity of the author. The mathematical form suggests that on a field or basinwide scale, the sorptivity of the surface soil is log normally distributed.

76:02G-100
INFILTRATION ANALYSIS AND PERTURBATION METHODS III. VERTICAL INFILTRATION,
Babu, D.K.
City College, Department of Mathematics, New York.
Water Resources Research, Vol. 12, No. 5, p 1019-1024, October 1976. 3 fig, 1 tab, 7 ref.

Descriptors: *Infiltration, *Mathematical studies, *Unsaturated flow, Moisture content, Boundaries (Surfaces), Theoretical analysis, Equations,Velocity, Diffusivity, Permeability, Numerical analysis.

Simple perturbation methods continue to yield good results in the solution of the problem of vertical infiltration of water into unsaturated soils. The initial approximation is valid for all times and gives useful information about important flow characteristics. The required computations are always direct and simple. Some numerical work pertaineng to Yolo light clay was presented to exhibit the advantages, relevance, and simplicity of the present analysis compared to other existing works on this topic.

76:02G-101
INFILTRATION ANALYSIS AND PERTURBATION METHODS II. HORIZONTAL ABSORPTION,
Babu, D.K.
City College, Department of Mathematics, New York.
Water Resources Research, Vol. 12, No. 5, p 1013-1018, October 1976. 1 fig, 1 tab, 12 ref, 1 append.

Descriptors: *Infiltration, *Absorption, *Mathematical studies, Equations, Theoretical analysis, Unsaturated flow, Diffusivity, Moisture content, Boundaries (Surfaces).

Perturbation methods are employed to analyze the horizontal absorption of moisture in unsaturated soils. The reported study applied to absorption under the general diffusivity function, subject to constant boundary concentration. The concept of the wetting front moving with a finite velocity played a fundamental role in this set of papers. The solution emerges as a series of terms that can be explicitly calculated in terms of the integrals involving diffusivity functions. The examples of exponential and constant diffusivity functions, as well as the case of Yolo light clay, were computed to one or two terms to exhibit the advantages over, and the good agreement with, other published data of Parlange, Philip, etc. The method possesses great potential, and in a subsequent paper the study of vertical infiltration will be presented by utilizing the perturbation mechanism.

76:02G-102
THE DIFFERENT FORMS OF MOISTURE PROFILE DEVELOPMENT DURING THE REDISTRIBUTION OF SOIL WATER AFTER INFILTRATION,
Youngs, E.G., and Poulovassilis, A.
Agricultural Research Council, Unit of Soil Physics, Cambridge, England.
Water Resources Research, Vol. 12, No. 5, p 1007-1012, October 1976. 7 fig, 18 ref.

Descriptors: *Infiltration, *Soil water movement, *Model studies, Mathematical models, Laboratory tests, Soil water, Soil moisture, Water spreading, Moisture content, Soils, Equations, Porous media, Percolation, Pervious soils, Soil physical properties.

Two different forms of moisture profile development may occur during the redistribution of soil water after infiltration. In one, the profile shape continues to be similar to that profile developed during the infiltration process, with a fairly uniform water content region near the soil surface above a steep wetting front; and the rate of redistribution is inversely related to the infiltration depth. In the other, water drains from near the surface to appear as a step in the moisture profile below the wetting front at the cessation of infiltration; and the rate of redistribution is directly related to infiltration depth. Classical theory of soil water movement was shown to account for both forms of moisture profile development, which depend on the moisture profile shape at the cessation of infiltration and on the soil water properties of the porous material. Experimental results of moisture profile development in a sand column illustrated how different profile forms develop as the depth of infiltration is increased and, by inclining the experimental column, how they depend on the relative importance of the soil water pressure head gradients compared with that of gravity.

76:02G-103
EXTRACTION OF SOIL WATER USING CELLULOSE-ACETATE HOLLOW FIBERS,
Jackson, D.R., Brinkley, F.S., and Bondietti, E.A.
Oak Ridge National Laboratory, Oak Ridge, Tennessee.
Soil Science Society of America Journal, Vol. 40, No. 2, p 327-329, March-April 1976. 5 fig, 1 tab.

Descriptors: Soil water, Soils, Soil investigations, Soil properties, Soil chemistry, Laboratory tests, Sampling, Greenhouses.

Cellulose-acetate hollow fibers were used to extract soil solutions from soil columns. The fibers have unique characteristics of small diameter and high flexibility and permeability which are ideally suited for use in soils. Two experiments were completed to demonstrate the usefulness of the hollow fibers. A 109Cd-tagged soil column was leached with distilled water, and subsequently soil water was extracted with the fibers. The effective radius of soil-water extraction by the fibers was evaluated. The results show that the fibers can extract soil solution for chemical assay at moisture levels ranging from 20 to 50%. Applications of this technique include sampling soil solution from greenhouse pots and experimental microcosms.

76:02G-104
COMPARISON OF FIVE KINETIC MODELS FOR ORTHOPHOSPHATE REACTIONS IN MINERAL SOILS,
Enfield, C.G., Harlin, C.C., and Bledsoe, B.E.
United States Environmental Protection Agency, Office of Research and Development, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma.
Soil Science Society of America Journal, Vol. 40, No. 2, p 243-249, March-April 1976. 3 fig, 2 tab, 31 ref.

Descriptors: Kinetics, Soils, Soil investigations, Soil properties, Soil chemical properties, Adsorption, Diffusion, Sorption.

The kinetics of orthophosphate sorption with 25 mineral soils have been experimentally measured under laboratory conditions. The 25 mineral soils represent a wide range of physical and chemical properties. Regression analyses have been performed fitting the experimental data to five kinetic models. The five kinetic models include: a linearized first-order sorption, a first-order Freundlich sorption, an empirical function, a diffusion-limited Langmuir sorption, and a diffusion-limited Freundlich sorption. Mean correlation coefficients of 0.81, 0.83, 0.84, 0.86, and 0.88 were obtained for the models, respectively.

76:02G-105
ESTIMATION OF COMPONENTS OF SOIL CATION EXCHANGE CAPACITY FROM MEASUREMENTS OF SPECIFIC SURFACE AND ORGANIC MATTER,
Curtain, D., and Smillie, G.W.
University College, Department of Soil Science, Dublin, Ireland.
Soil Science Society of America Journal, Vol. 40, No. 3, p 461-462, May-June 1976. 3 tab, 14 ref.

Descriptors: *Cation exchange, Organic matter, Soil textures, Soils, Soil properties, Soil investigations.

Cation exchange capacities of Irish soils developed from a wide range of parent materials were found to be highly correlated with organic matter content and specific surface but not with clay content. Multiple regression analysis showed that organic matter in combination with specific surface accounted for 97% of the variation in CEC whereas organic matter and clay content only accounted for 58% of the variation. The better correlation between CEC and specific surface than between CEC and clay content, is attributed to the ability of surface area measurements to reflect the presence of phyllosilicates in silt and sand fractions of soils and to the fact that these minerals have less variable surface charge densities than cation exchange capacities. It is proposed that specific surface provides a better estimate than clay content, of the mineral component of CEC for soils of varying mineralogy.

76:02G-106
RELATION BETWEEN THE KINETICS OF NITROGEN TRANSFORMATION AND BIOMASS DISTRIBUTION IN A SOIL COLUMN DURING CONTINUOUS LEACHING,
Starr, J.L., and Parlange, J.-Y.
Connecticut Agricultural Experiment Station, New Haven, Connecticut.
Soil Science Society of America Journal, Vol. 40, No. 3, p 458-460, May-June 1976. 1 fig, 5 ref.

Descriptors: Nitrogen, Leaching, Kinetics, Microorganisms, Soils Soil investigations.

Nitrogen concentration profiles in soil columns with associated microbial distributions have been used in the past to deduce the kinetics of nitrogen transformations during steady leaching. Owing to the many factors which control microbial reaction kinetics in continuous flow systems, the effect of biomass variation and order of reaction cannot be separated by simply measuring steady-state concentrations profiles. It is shown here that in practice these measurements only lead to some average kinetics for the system observed, even when the microbe distribution is measured independently. Previously published experimental data in conjunction with a derived expression are used to illustrate the point.

76:02G-107
POTASSIUM RELEASE FROM SAND, SILT, AND CLAY SOIL SEPARATES,
Munn, D.A., Wilding, L.P., and McLean, E.O.
North Carolina State University, Department of Soil Science, Raleigh, North Carolina.
Soil Science Society of America Journal, Vol. 40, No. 3, p 364-366, May-June 1976. 6 tab, 10 ref.

Descriptors: Soils, Soil investigation, *Potassium, Soil texture, Soil properties, Soil chemistry, Nutrients, Soil chemical properties, Particle size.

Four Ohio soils of divergent mineralogy were fractionated into sand, silt, and clay-sized separates after dispersion with an ultrasonic probe. Samples were extracted for 10 days with 0.01M CaCl2 with the solution being changed each day. There was a wide range in daily and cumulative K release among the four soils for the same particle size and for different particle sizes within the same soil. When weighted according to particle size distribution of the soil, the clay was found to contribute 30-74%; silt 24-56%; and sand 3-21% of the total K released by the sum of the three separates. In all four soils, the clay separate released the most K per unit weight. The apparent rate constants for K release from the sand and clay separates were similar and generally higher than that for the silt separates.

76:02G-108
WATER CONTENT AND BULK DENSITY DURING WETTING OF A BENTONITE-SILT COLUMN,
Nofziger, D.L., and Swartzendruber, D.
Oklahoma State University, Department of Agronomy, Stillwater, Oklahoma.
Soil Science Society of America Journal, Vol. 40, No. 3, p 345-348, May-June 1976. 6 fig, 14 ref.

Descriptors: *Soil moisture, Soil water, Bulk density, Soil water movement, Soils, Soil properties, Clays, Seepage, Saturated flow, Unsaturated flow.

An improved method of dual-energy gamma-ray attenuation was used to measure water content and bulk density rapidly and accurately, during one-dimensional, unsaturated water movement into a column of an equal-part mixture of initially air-dry, highly swelling bentonite and silt. The bulk density near the inlet end of the column decreased rapidly as water entered. Since the ends of the column were confined, the expansion of the wetted bentonite-silt produced a compression in the remaining air-dry portion of the column. Several water-content variables were plotted against the so-called reduced material coordinate m/t(1/2) (Boltzmann variable expressed in terms of the material coordinate m and time t). Neither the volumetric water content not the volumetric water ratio would coalesce the data when plotted against m/t(1/2). In contrast, a plot of water saturation vs. m/t(1/2) did coalesce the data into a single curve, except for very early times at positions nearer than 1 cm to the water inlet.

76:02G-109
DENITRIFICATION KINETICS IN SOIL SYSTEMS: THE SIGNIFICANCE OF GOOD FITS OF DATA TO MATHEMATICAL FORMS,
Kohl, D.H., Vithayathil, F., Whitlow, P., Shearer, G., and Chien, S.H.
Washington University, Department of Biology, Saint Louis, Missouri.
Soil Science Society of America Journal, Vol. 40, No. 2, p 249-253, March-April 1976. 5 fig, 10 ref.

Descriptors: Denitrification, Kinetics, Soils, Soil properties, Saturation.

The loss of NO3(-) added to two central Illinois soils was determined in experiments in which the soils were incubated under waterlogged conditions. The loss was measured as a function of substrate concentration in one experiment in which samples were incubated for a single time (24 hours) and as a function of time in a second experiment in which the concentration of the added NO3(-) was held constant (200 ppm NO3(-)-N). The rate of loss of NO3(-) was about 5.5 times higher in one of the soils than in the other. This difference was largely overcome by the addition of glucose (1% with respect to the soil) which also greatly enhanced the rate of denitrification in both soils. The experimental points representing the rate of NO3(-) loss plotted as a function of the concentration of added NO3(-), were equally well fit by Michaelis-Menten and exponential equations as well as by the solution to a pair of nonlinear differential equations representing a system in which the product of one reaction is a substrate in a second sequence.

76:02G-110
THE RESISTANCE OF INTACT MAIZE ROOTS TO WATER FLOW,
So, H.B., Aylmore, L.A.G., and Quirk, J.P.
New England University, Department of Agronomy and Soil Science, Armidale, New South Wales, Australia.
Soil Science Society of America Journal, Vol. 40, No. 2, p 222-225, March-April 1976. 2 fig, 3 tab, 9 ref.

Descriptors: Tensiometers, Maize, Root systems, Soil water, Soil water movement.

Using a novel tensiometer-potometer system relationship between the root resistance to water flow of maize and the water potential of the root tissue has been examined. Over the range of water potentials used, a linear relation has been observed in contrast to previous observations. Calculations using published data indicate that the rhizosphere resistance is of the same order of magnitude as the root resistance when the soil moisture potential of the rhizosphere is about -1 to -2 bars.

76:02G-111
CORRELATION OF PLANT MANGANESE WITH EXTRACTABLE SOIL MANGANESE AND SOIL FACTORS,
Randall, G.W., Schlute, E.E., and Corey, R.B.
Minnesota University, Southern Experiment Station, Waseca, Minnesota.
Soil Science Society of America Journal, Vol. 40, No. 2, p 282-287, March-April 1976. 6 tab, 19 ref.

Descriptors: *Manganese, Soils, Soil properties, Soil chemical properties, Oats, Organic matter, Greenhouses, Soil investigations, Wisconsin.

The availability of Mn on 37 low and 20 high organic matter Wisconsin soils was determined by growing oats and ryegrass, respectively, in consecutive greenhouse studies. The Mn uptake values were used to develop prediction equations by means of multiple regression analysis with Mn extracted by various extracting solutions (18 extractants for the low and 13 for the high organic matter soils) plus various functions of soil pH and organic matter as the independent variables. On the low organic matter soils (O.M. < 6%), using only the Mn test, the best prediction values with uptake were obtained with total Mn, and with the 0.1N H3PO4 and 0.01M EDTA in 1N NH4OAc extractants (sq R = 57, 50 and 49%, respectively). Inclusion of soil pH and organic matter with the soil test values resulted in Mn uptake being predicted best by the 0.01M and 0.05M EDTA extractants (sq R = 68% for both). The contribution of the soil test in the prediction equation was strongest when the 0.1N H3PO4, 0.01M EDTA in 1N NH4OAc, 0.05M EDTA or DTPA (pH 7.3) extractants were used.

76:02G-112
EXCHANGE AND HYDRATION PROPERTIES OF CU(2+) ON MIXED-ION NA(+) - CU(2+) SMECITES,
McBride, M.B.
Cornell University, Department of Agronomy, Ithaca, New York.
Soil Science Society of America Journal, Vol. 40, No. 3, p 452-456, May-June 1976. 4 fig, 1 tab, 20 ref.

Descriptors: *Cation adsorption, *X-ray diffraction, Clays, Montmorillonite, Soils, Soil investigations, Soil properties, Soil chemistry.

The exchange of Na(+)-montmorillonite with Cu(2+) was studied using X-ray diffraction, electron spin resonance (ESR) and a specific Cu(2+) electrode in order to investigate the hydration and exchange properties of mixed Cu(2+) - Na(+) clay systems. With < 30% of the exchange sites occupied by Cu(2+), the clays behave much as pure Na(+)-montmorillonite and swell freely in water. Larger exchange levels of Cu(2+) produce more ordered interlayers at low relative humidities. At high relative humidities, this ordered structure is reduced and a solution-like environment is produced as the alumino-silicate sheets further separate. Exchange isotherms demonstrate a large preference for Cu(2+) over Na(+) at low Cu(2+) exchange levels, but preference for Na(+) at high Cu(2+) levels. In contrast, Cu(2+) - Mg(2+) exchange does not show this effect, indicating that certain exchange sites on the silicate structure preferentially adsorb divalent cations. Thus, Cu(2+) ions are effectively removed from solution by Na(+) - montmorillonite, but are not adsorbed in preference to other divalent cations.

76:02G-113
SOLUTION OF THE ONE-DIMENSIONAL LINEAR MOISTURE FLOW EQUATION WITH IMPLICIT WATER EXTRACTION FUNCTIONS,
Lomen, D.O., and Warrick, A.W.
Arizona University, Department of Mathematics, Tucson, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 3, p 342-344, May-June 1976. 3 fig, 2 tab, 4 ref.

Descriptors: Model studies, Soil water, Soil water movement, Soil moisture, Irrigation, Irrigation effects.

Analytical solutions of the one-dimensional steady-state moisture flow equation are presented for several functions modeling soil water extraction. These functions depend directly on the matric flux potential and thus are implicit with depth. A constant surface flux was assumed. Graphs of the matric flux potential and cumulative uptake are given depicting the effect of model parameters and comparing different water extraction functions. The results are useful in obtaining a variety of water extraction distributions.

76:02G-114
WATER TRANSPORT FROM ROOTS TO SOIL,
Molz, F.J., and Peterson, C.M.
Auburn University, Department of Civil Engineering, Auburn, Alabama.
Agronomy Journal, Vol. 68, No. 6, p 901-904, November 1976. 4 fig, 20 ref.

Descriptors: Root systems, Root zone, Soil water, Soil moisture, Cotton, Soil water movement, Mathematical models, Model studies, Hysteresis.

Numerous studies have indicated that water can flow from roots to soil (negative direction) but little can be concluded about the magnitude of such a flow. Therefore, experiments were performed on potted cotton plants to compare the magnitude of water transport in the positive (soil to roots) and negative directions. Experimental results were also compared qualitatively with the predictions derived from mathematical models simulating root water uptake. Each plant was left unwatered in an environmental chamber to dry the soil from field capacity to near the --15 bar percentage. After drying, the stem was severed under water and the resulting water flow from roots to soil recorded by weight changes. Results indicated that water flow in the negative direction is small (1:36 during a 110-hour period) compared to flow in the positive direction. This difference is thought to be due to a hysteretic, unsaturated, and possibly non-Darcian flow phenomenon or the generation of growth-related water potentials. Contemporary mathematical water extraction models ignore both phenomena and, therefore, would be expected to overestimate flows in the negative direction if "calibrated" to predict correctly flows in the positive direction.

76:02G-115
SHALLOW SUBSURFACE DRAINAGE-FIELD PERFORMANCE.
Fausey, N.R. and Brehm, R.D.
Agricultural Research Service, United States Department of Agriculture, Department of Soil Science, North Central Region.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1082-1084, Special Edition 1976. 3 fig, 2 tab, 8 ref.

Descriptors: *Subsurface drainage, *Drainage, Drainage practices, Drainage effects, Soil water.

This field study shows that shallow subsurface drains (40 cm deep) remove as much soil water as deeper drains (95 cm deep) during the growing season in the Toledo soil. There was no structural damage to the shallow plastic draintubes from farming operations. Thus, shallow drainage systems offer great promise as a drainage technique for a large group of soils for which subsurface drainage is not now recommended.

76:02G-116
GRAIN SORGHUM RESPONSE TO INUNDATION AT THREE GROWTH STAGES,
Howell, T.A., Hiler, E.A., Zolezzi, O., and Ravelo, C.
Texas A & M University, Department of Agricultural Engineering, College Station, Texas.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 876-880, Special Edition, 1976. 4 fig, 3 tab, 14 ref.

Descriptors: *Grain sorghum, Crop response, Crop production, Drainage, Drainage practices.

Drainage design is often limited by characterizing the crop response to specific water inputs. This research evaluated grain sorghum response to inundation periods of twelve days at the early vegetative, early boot, and heating growth stages for grain sorghum. Twelve days of inundation at early vegetative growth reduced the plant stand by 5 percent and yield by 30 percent. Inundation for 12 days at the early boot stage reduced the plant stand by 2 percent and yield by 26 percent. Inundations after grain sorghum heading did not reduce yield. Inundation may cause further yield reduction by physical damage to the crop such as lodging and by increased time to maturity.

76:02G-117
DIFFUSION AND MASS FLOW OF NITRATE-NITROGEN INTO CORN ROOTS GROWN UNDER FIELD CONDITIONS,
NaNagara, T., Phillips, R.E., and Leggett, J.E.
Royal Thai Ministry of Agriculture, Department of Agronomy, Bangkok, Thailand.
Agronomy Journal, Vol. 68, No. 1, p 67-72, January-February 1976. 4 fig, 3 tab, 10 ref.

Descriptors: Nitrogen, Nitrate, Corn, Crop response, Nutrients, Fertilizers, Fertilization, Mass flow, Model studies.

Nitrate-nitrogen, the most important source of N of non-leguminous plants, is soluble in soil water and is transported to plant roots by both mass flow and diffusion. It is, therefore, important to evaluate the relative importance of each of these two mechanisms of transport of NO3(-)N to plant roots and the environmental conditions under which each is the dominant mechanism of transport. The objective of this paper was to present measurements of plant and soil parameters necessary for estimating accumulation of N grown under field conditions with the use of a theoretical model and to compare estimates of accumulation of N in the corn plant with measured accumulation in the plant.

76:02G-118
SUBSOIL CHISELING AND SLIP PLOWING EFFECTS ON SOIL PROPERTIES AND WHEAT GROWN ON A STRATIFIED FINE SANDY SOIL,
Kaddah, M.T.
Imperial Valley Conservation Research Center, Department of Soil Science, Brawley, California 92227
Agronomy Journal, Vol. 68, No. 1, p 36-39, January-February 1976. 3 fig, 2 tab, 14 ref.

Descriptors: Soil physical properties, Soil properties, Wheat, Soil investigations, California, Crop response, Infiltration, Bulk density, Root development.

Positive crop growth response to deep tillage in sandy soils has been observed in Imperial Valley, California. Very little information is available, however, on the effect of different deep tillage operations and the possible causes of the beneficial effects of deep tillage. The present field study was conducted on a stratified fine sandy soil to evaluate the effect of subsoil chiseling and slip plowing to a depth of 90 cm on wheat yield and soil properties. Conventional soil disking to 20 cm depth was compared with two subsoil chiseling and two slip plowing treatments. Subsoil chiseling was on 1-m centers in one and in two directions, and slip plowing was on 2-m centers in one or two directions. The two directions of deep tillage were at right angles to each other. Significant increases in wheat yield resulted from deep tillage. Grain yield (metric tons/ha) were: 4.50 for disking; 5.15 for subsoil chiseling in two directions; 5.73 for slip plowing one direction; and 6.32 for slip plowing in two directions.

76:02G-119
SOIL PHYSICAL CONDITIONS AFFECTING RICE ROOT GROWTH: BULK DENSITY AND SUBMERGED SOIL TEMPERATURE REGIME EFFECTS,
Kar, S., Varade, S.B., Subramanyam, T.K., and Ghildyal, B.P.
Indian Institute of Technology, Department of Agricultural Engineering, Kharagpur, West Bengal, India.
Agronomy Journal, Vol. 68, No. 1, p 23-26, January-February 1976. 5 tab, 15 ref.

Descriptors: Root development, Rice, Soil physical properties, Bulk density, Temperature, Greenhouse experiments.

Information is lacking on the performance of the rice plant due to variations in temperature regimes in association with other soil physical properties. This investigation, carried out under controlled greenhouse conditions, evaluate the influence of temperature and mechanical impedance of soil, as well as of their interaction, on root and shoot growth of rice. Four submerged soil temperature regimes thermoregulated in water baths, indicated that the maximum root and shoot growth of rice occurred at 37 to 25 C. Irrespective of the bulk density of soil, the total number of roots at the base and the dry weight and volume of the rice root system significantly increased as the submerged soil temperature regime increased from 27 to 15 C to 37 to 25 C, but decreased at 42 to 30 C.

76:02G-120
SATURATED AND UNSATURATED FLOW TO PARALLEL DRAINS,
Skaggs, R.W. and Tang, Y.
North Carolina State University, Department of Geological and Agricultural Engineering, Raleigh, North Carolina.
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR2, p 221-238, June 1976. 14 fig, 19 ref.

Descriptors: Drainage, Drainage engineering, Drainage practices, Soil water movement, Soil properties, Hydraulic conductivity, Drainage effects, Drainage systems.

The purpose of this paper is to present solutions to the two-dimensional Richards equation for open ditch drainage and to compare these solutions with conventional more approximate methods. Specifically the objectives are to: (1) Solve the Richards equation for drainage boundary conditions using numerical methods developed by Amerman (1); (2) compare these solutions to solutions to solutions of the more approximate Boussinesq equation, which are normally used for drain spacing predictions; and (3) determine the effect of error in the soil properties on the solutions and to examine the relative merits of the exact and approximate methods in view of the field variability of these properties.

76:02G-121
SOLUTIONS TO GREEN-AMPT INFILTRATION EQUATION,
Li, R., Stevens, M.A. and Simons, D.B.
Colorado State University, Department of Civil Engineering, Fort Collins, Colorado.
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR2, p 239-248, June 1976. 1 fig, 1 tab, 14 ref.

Descriptors: Infiltration, Soil water movement, Mathematical studies.

Two simple methods of solving the one-dimensional infiltration equations have been developed in this study. The explicit solution is an approximation obtained by employing a power series expansion of the logarithmic term in the infiltration equation. The maximum error resulting from employing this simple explicit solution is 8%. The implicit 'exact' solution is obtained by refining the explicit solution using the second-order Newton method. The maximum error resulting from employing the implicit solution is 0.03%. These new methods have advantages over other solutions in that they are derived from the theory of power series expansion and the errors due to approximation can be evaluated theoretically. Moreover, the two methods are simple and easy to use either with a desk calculator or in a digital computer. and they are applicable without limitation on ranges.

76:02G-122
MISCIBLE DISPLACEMENT IN SOILS,
Smajstrla, A.G., Barnes, P.L., and Reddell, D.L.
Texas A and M University, Department of Agricultural Engineering, College Station, Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 21 p, 8 fig, 1 tab, 6 equ, 8 ref.

Descriptors: Soil properties, Ions, Soil chemistry, Soil water movement.

A description of field experimental plots being used to determine soil hydrologic properties and to monitor movement of ions in solution is presented. Steps in the analysis of field data are also itemized, including calculation of soil hydrologic characteristic curves and the calibration procedures required for the instrumentation described.

76:02G-123
WATER AND AIR MOVEMENT IN A BOUNDED DEEP HOMOGENEOUS SOIL,
Sonu, J. and Morel-Seytoux, H.J.
Seoul National University, Department of Civil Engineering, Seoul, Korea.
Journal of Hydrology, Vol. 29, p 23-42, 1976. 14 fig, 23 ref.

Descriptors: Infiltration, Soil moisture, Soil water, Water table, Soil properties.

A methodology, based on the knowledge of the characteristic curves of the soil, is presented to predict the infiltration rate into a soil, the evolution of the water content in the soil and the evolution of the water table under natural hydrological boundary conditions. Comparison with experimental results shows the method to be accurate. In filtration rate curves are obtained for a number of situations involving different boundary and/or initial conditions. The results confirm the known experimental facts and the field observations that soil-air behavior is an important factor in infiltration phenomena.

76:02G-124
CALCULATION AND PREDICTION OF THE SALT REGIME OF LOWLAND SOILS UNDER INFLUENCE OF GROUNDWATER SALINIZATION,
Plamenac, N., Vikovik, M., and Matic, M.
'Jaroslav Cerni' Institute for Development of Water Resources, Belgrad, Yugoslavia.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 277-289, 9 fig, 5 ref.

Descriptors: Salinity, Saline soil, Soil properties, Clays, Salt balance, Salts, Soil water, River systems, Groundwater.

The area of lowland alluvial plain along the Danube in the zone of Belgrade is provided with embankments controlling the river floods that results in occurrence of secondary salinization of the soil. Owing to the construction of the 'Djerdap' large hydroelectric power plant, the water level regime in the river is being changed during minimum and medium discharges. This may result in aggravating the groundwater regime and in accelerating the process of soil salinization. In order to realize the rate of salinization in altered conditions and to estimate the influence of various measures, calculation and prediction of the salt regime of lowland soils has been made. The area considered is, in hydraulic view, a two-layer porous medium with clay prevailing in the surface layer. The lower, water-bearing layer, being hydraulically linked with the Danube, consists of sand and gravel. For such hydrogeological conditions a methodology is elaborated for calculation of the groundwater regime, presented the basis for calculation and prediction of the salt regime of lowland soils in given conditions.

76:02G-125
MANAGING SALINE WATER FOR IRRIGATION,
Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Lubbock, Texas
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976. 618 p.
(see 76:05C-002)

76:02G-126
RESISTANCE TO SODA SALINIZATION OF SOME IRAQI SOILS,
Alzubaidi, A.H.
College of Agriculture, Department of Soil, Abu-Ghraib, Iraq.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 333-338. 2 tab, 10 ref.

Descriptors: Irrigation water, Soil properties, Calcium, Magnesium, Soil Chemistry, Saline water.

In evaluation of irrigation water containing soda, it is not sufficient to determine only the Residual Sodium Carbonate (RSC) according to Eaton. Soil resistence to soda formation values (c-values) which consider the soil properties must also be determined. Soil resistance to soda formation for thirty-eight soil samples collected from different locations of Iraq were tested accordingly in this work. The obtained results show that most of these samples have weak to moderate resistance to soda formation. Soil samples with no resistance to soda formation were not noticed. The value of soil resistance to soda formation are determined by the amount of soluble and exchangeable calcium and magnesium in soil samples. According to our findings irrigation water and saline water containing soda could be used under Iraqi conditions for irrigation of some saline soils and during the first stages of their reclamation. The obtained data of this work have a considerable value in evaluation of saline water containing soda for irrigation and reclamation purposes.

76:02G-127
MODELS FOR PREDICTING THE IMPACT OF IRRIGATION ON SOIL SALINITY.
Bresler, E.
Agricultural Research Organization, Institute of Soils and Water, Division of Soil Physics, Bet Dagan, Israel, and The Hebrew University of Jerusalem, Israel.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 299-315. 7 fig, 13 ref.

Descriptors: Model studies, Salinity, Salts, Irrigation, Irrigation effects, Saline soil, Simulation analysis, Soil physical properties, Hydraulic conductivity, Soil water, Computer programs, Optimization.

Prediction of salinization and sodication for irrigated soils is important in establishing management practice directed toward reclamation of saline soils. Models are used which approximate the physical soil conditions by mathematical expressions describing the simultaneous transport of water and salt. The governing non-linear partial differential equations are supplemented by initial and boundary conditions appropriate to soil salinization and reclamation.

76:02G-128
CONVECTIVE TRANSPORT OF SOLUTES IN AND BELOW THE ROOT ZONE.
Raats, P.A.C.
United States Salinity Laboratory, Riverside, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 290-298. 4 fig, 10 ref.

Descriptors: Return flow, Salinity, Saline water, Irrigation, Irrigation effects, Water quality, Dissolved solids, Root zone.

The first objective of research related to the management of saline water for irrigation is to find the space-time trajectories of bits of water. The second objective is to determine the change in quality of these bits of water, in particular the changes in solute concentration due to evaporation at or near the soil surface and selective uptake of water by plant roots. Within the root zone, the details of the water movement and of the changes in concentration depend on the relative magnitude of the components of the water balance, on the distribution of the water uptake, and on the irrigation frequency. Below the root zone, the water table and the drainage facility. If the drains or ditches are widely spaced relative to the depth of the first impermeable layer, then the influence of the details of the flow near the drains or ditches is small, and the transit times tend to be exponentially distributed. This in turn implies some simple input/output relationships and provides a good reference for comparison of more complicated geometrics and distributions of inputs and outputs.

SECTION VIII

WATER CYCLE

LAKES (GROUP 02H)

76:02H-001
A CHLOROPHYLL A MODEL AND ITS RELATIONSHIP TO PHOSPHORUS LOADING PLOTS FOR LAKES,
Chapra, S.C. and Tarapchak, S.J.
Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, Ann Arbor, Michigan 48104
Water Resources, Research, Vol. 12, No. 6, p 1260-1264, December 1976. 4 fig, 2 tab, 21 ref.

Descriptors: Chlorophyll, Model Studies, Phosphorus, Sedimentation, Sediments, Eutrophication, Lake beds, Lake sediments.

A model predicting the summer concentration of chlorophyll a in a phosphorus-limited lake is derived from simple empirical and semitheoretical relationships. The model is rearranged and expressed as a phosphorus loading plot which agrees closely with the predictions of Vollenweider's model. The model can be used to gain insight into the phosphorus loading concept. The primary conclusion is that a lake's tolerance to phosphorus loading is a function of two processes: sedimentation and flushing rate. At low areal water loads, in-lake forces which remove phosphorus to the sediments predominate. A high areal water loads, flushing of phosphorus through the lake's outlet is the factor governing eutrophication. The importance of the steady state assumption is also demonstrated by using data for Lake Washington.

SECTION IX

WATER CYCLE

WATER AND PLANTS (GROUP 02I)

76:02I-001
LEAD EFFECTS ON SEVERAL ENZYMES AND NITROGENOUS COMPOUNDS IN SOYBEAN LEAF,
Lee, K.C., Cunningham, B.A., Chung, K.H., Paulsen, G.M., and Liang, G.H.
Chung-Hsin University, Taiwan.
Journal of Environmental Quality, Vol. 5, No. 4, p 357-359, October-December 1976. 3 tab, 24 ref.

Descriptors: *Enzymes, *Lead, *Heavy metals, Soybeans, Ammonia, Proteins, Calcium, Phosphorus, Leaves, Respiration.

To obtain further evidence on the nature of lead toxicity in plants, the Pb(2+) effect of several enzyme activities and nitrogenous compounds in soybean was investigated. Soybean seedlings were grown in culture solution treated with lead nitrate so that final concentrations of lead Pb(2+) were 0, 20, 60, and 100 mg/liter. Soybean leaves were analyzed 10 days after lead was added to the solution. Results showed increased respiration rate, increased activities of acid phosphatase, peroxidase and alpha-amylase, and increases in soluble protein and ammonia. There was no significant change in malic dehydrogenase, and total free amino acids. A decrease was observed for glutamine synthetase activity and nitrate. Leaf calcium and phosphorus decreased as the lead concentration was increased in the culture solution. Increased activities of the hydrolytic enzymes and peroxidase indicates that the lead treatment enhances senescence.

76:02I-002
SIMULATION OF PLANT GROWTH BY HUMIC SUBSTANCES,
Lee, Y.S., and Bartlett, R.J.
Vermont University, Department of Plant and Soil Science, Burlington, Vermont.
Soil Science Society of America Journal, Vol. 40, No. 6, p 876-879, November-December 1976. 1 fig, 6 tab, 15 ref.

Descriptors: Organic matter, Corn, Algae, Nutrients, Phosphorus, Iron, Growth rates, Crop response.

Humic substances prepared by different techniques of extraction and from different sources of organic materials were tested for their effects on growth of corn seedlings and algae. Stimulating effects were confirmed with optimum concentrations about 5 ppm C as Na-humate for corn and 60 ppm for algae. With corn, the increase was 30 to 50% in nutrient solution of low organic matter soil; with algae, about 100%. Variation of effects among humic acids derived from different organic materials was not great. The concentrations of elements in corn seedlings did not show any correlation with yield or humic acid level except for P and Fe. Phosphorus concentration was increased with increasing levels of humic acid regardless of the yield response. Higher Fe concentration in the plant tops and lower in roots was observed in the treatments with humic acid. The application of humic acid to a soil low in organic matter or to nutrient solution gave the greatest growth response, or even a slightly negative response, indicating that the natural soil, without extraction, supplied optimim amount of humic substances to the plants. It is suggested that a test be developed to predict whether a given soil can furnish an optimum level of humic substances.

76:02I-003
INTERACTION OF WATER POTENTIAL AND TEMPERATURE EFFECTS ON GERMINATION OF THREE SEMI-ARID PLANT SPECIES,
Sharma, M.L.
Commonwealth Scientific and Industrial Research Organization, Division of Land Resources Management, Wembley, Australia.
Agronomy Journal, Vol. 68, No. 2, p 390-394, March-April 1976. 2 fig, 1 tab, 16 ref.

Descriptors: *Osmotic pressure, *Germination, *Temperature, *Soil moisture, Planting management, Semiarid climates, Environmental effects, Moisture stress, Thermal stress, *Australia, Grasses, Shrubs, Viability.

The interactive effects of temperature with matric and osmotic potential on the germination of Danthonia caespitosa, Atriplex nummularia and A. vesicaria are reported. The rate and total germination of all three dryland species from New South Wales decreased as water potential declined. Germination rates increased with increasing temperature, but final germinations were greatest at intermediate temperatures (20-25 C). Low water potentials during optimum temperatures produced the best germination. Osmotic and matric potential effects were qualitatively similar, but osmotic inhibition decreased at low temperatures. Both Atriplex germinated at extreme temperatures (5 and 40 C), while D. Caespitosa failed to germinate. At low water potential (-15 bars) A. nummuralia germinated from 15 to 40C and D. caespitosa at 25C, while A. vesicara germinated poorly at all temperatures. A. nummularia had the greatest resistance to environmental stress. Atriplex spp may germinate after rains during summer as well as winter; Danthonia germination is likely only during spring and autumn.

76:02I-004
YIELD-NUTRIENT ABSORPTION RELATIONSHIPS AS AFFECTED BY ENVIRONMENTAL GROWTH FACTORS,
Terman, G.L., Khasawneh, E.F., Allen S.E.,and Engelstad, O.P.
National Fertilizer Development Center, Muscle Shoals, Alabama.
Agronomy Journal, Vol. 68, No. 1, p 107-111, January-February, 1976.
7 fig, 17ref.

Descriptors: *Plant growth, *Nutrients, *Crop production, *Soil temperature, *Soil environment, Nitrogen, Phosphorus, Corn(Field), Oats, Growth rates, Root development, Soil management, Crop response, Absorption.

Temperature effects on crop yield-nutrient concentration and uptake relationships were evaluated in three greenhouse pot experiments and as reported in the literature on such factors. Several rates of applied nitrogen and phosphorous were weeks at three combinations of day length and temperature; corn grown for 4 weeks at water bath temperatures of 16 and 27C; and corn grown for 3 and 6 weeks to compare P rates and temperatures of 16 and 21C and at ambient temperatures (25 to 35C). Plant nutrient concentrations, especially of P, increase with greater soil temperatures in short-duration experiments, with little yield response to temperature. Where marked yield response occurs, dilution of plant nutrient concentrations but higher uptakeare the dominant trends with temperature increase up to the optimum for each crop species; the opposite trend usually occurs at nutrient release under higher temperatures varies with the soil fertility level and amounts of applied in uptake, especially with nutrients having limited mobility in the soil.

76:02I-005
PHOTOSYNTHATE DISTRIBUTION IN NATURAL STANDS OF SALT WATER CORDGRASS,
Hull, R.J., Sullivan, D.M., and Lytle, R.W. Jr.
Rhode Island University, Rhode Island Agricultural Experiment Station, Department of Plant and Soil Science, Kingston, Rhode Island 02881
Agronomy Journal, Vol. 68, No. 6, p 969-972, November-December 1976. 4 tab, 14 ref.

Descriptors: Tidal marshes, Estuarine environment, Grasses, Salt marshes.

Spartina alterniflora Loisel.is a major grass species of Atlantic coast tidal marshes which contributes heavily to the primary productivity of estaurine ecosystems. As human activity increases in marsh areas, the capability of marsh vegetation to withstand disturbance must be understood and constitute the basis for formulating sound management programs. Toward this end, the seasonal distribution of photoassimilated carbon was studied in S. alterniflora growing under natural conditions. Single culms were exposed to 14CO2 at various times during the 1970 and 1971 growing seasons. Plants were harvested 1, 3, and 7 days following exposure to 13CO2 subdivided into leaves, culm, rhizomes, and roots; and each portion assayed for 14C. Assimilate translocation reached a more or less stable distribution pattern within 24 hours. Throughout much of the growing season, most photosynthate was retained in leaf and culm tissue with less than 10% translocated to roots and rhizomes. Only during early autumn was substantial photosynthate translocated into rhizomes. This and seasonal carbohydrate levels within perennial organs indicate that the stability of S. alterniflora stands may be adversely affected by summer disturbance especially defoliation.

76:02I-006
NITROGEN ACCUMULATION AND TRANSLOCATION IN CORN GENOTYPES FOLLOWING SILKING,
Beauchamp, E.G., Kannenberg, L.W. and Hunter, R.B.
Guelph University, Department of Soil Science, Guelph, Ontario, Canada.
Agronomy Journal, Vol. 68, No. 2, p 418-422, March-April 1976. 3 fig, 5 tab, 6 ref.

Descriptors: Nitrogen, Fertilizers, Fertilization, Nutrients, Corn, Crop response, Crop Production.

The potential for improvement of N utilization in corn can depend on the existence of genotypic differences. Accordingly studies were conducted to determine if N translocation from the leaves and stalk to the ear during the period immediately following silking depended on the genotype. In 1970, the N concentration of individual leaf blades, stalk, and developing ears of four inbreds was determined at the silking stage and 14 and 28 days after silking. In a similar experiment in 1971, using bulked leaf blade samples, three of the inbreds plus their F1 hybrids were analyzed for N at silking and 24 days after silking. In 1970, the apparent translocation of N from individual leaf blades differed considerably depending on the inbred. Significant differences in N concentration in either the stalks or developing ears occurred among genotypes in 1970 and 1971. Appreciable differences were found in the apparent propensity of the inbreds to translocate N to the developing ear. In 1970, apparent N translocation during the 14 to 28 day period was greater than during the first 14 days following silking. The inbreds differed between years with respect to apparent N translocation suggesting a genotype times environment interaction.

76:02I-007
FIELD STUDIES OF THE CONDUCTANCE OF WHEAT LEAVES AND TRANSPIRATION,
Denmead, O.T. and Millar, B.D.
Commonwealth Scientific and Industrial Research Organization, Division of Environmental Mechanics, P.O. Box 821, Canberra City, Australian Capital Territory 2601, Australia
Agronomy Journal, Vol. 68, No. 2, p 307-311, March-April 1976. 4 fig, 9 ref.

Descriptors: Wheat, Transpiration, Stomata.

Light and water stress appear to be the main factors determining the short-term variation of stomatal aperture in the field but their joint influences have seldom been studied in the natural environment. We have examined the effects of the irradiances and water potentials of leaves of field-grown wheat plants on their conductances for water vapor and on canopy transpiration. Water potentials were measured by thermocouple psychrometry or estimated from water flow rates and plant resistances. Conductances were measured with a diffusion porometer or calculated from meteorological measurements inside the canopy. The latter data also permitted calculation of leaf irradiances and transpiration rates.

76:02I-008
NITROGEN UPTAKE CHARACTERISTICS OF CORN ROOTS AT LOW N CONCENTRATION AS INFLUENCED BY PLANT AGE,
Edwards, J.H. and Barber, S.A.
United States Department of Agriculture, Southeastern Fruit and Tree Nut Research Station, Byron, Georgia.
Agronomy Journal, Vol. 68, No. 1, p 17-19, January-February 1976. 1 fig, 2 tab, 9 ref.

Descriptors: Nitrogen, Corn, Fertilizers, Fertilization, Roots, Soil investigations, Greenhouse experiments.

Information is needed on the relation between concentration of N in solution, CN, and the rate of N uptake by corn roots in order to evaluate the soil and crop parameters affecting N fertilizer efficiency. Data on net N influx, In, vs. CN were obtained for N levels below 150 micro M on corn plants of seven ages ranging from 15 to 58 days (2 weeks after tasseling). It was determined by measuring rate of N depletion from the solution in which corn plants grew. Both NH+4 and NO-3 forms of N were used. The experiments were conducted in the growth chamber and greenhouse.

76:02I-009

NITRATE-N AND TOTAL N CONCENTRATION RELATIONSHIPS IN SEVERAL PLANT SPECIES,

Terman, G.L., Noggle, J.C., and Hunt, C.M.
Tennessee Valley Authority, National Fertilizer Development Center, Soils and Fertilizer Research Branch, Muscle Shoals, Alabama 35660
Agronomy Journal, Vol. 68, No. 4, p 556-560, July-August 1976. 5 fig, 2 tab, 9 ref.

Descriptors: Nitrate, Nitrogen, Nutrients, Greenhouse experiments, Corn, Phosphorus, Potassium, Crop response.

Accumulation of NO3-N in plants is important in regard to plant N nutritional status, in the formation of NO2-N toxic to animals and people consuming the plants, and as a producer of lethal gas in silos. This paper describes relationships between NO3-N and total N concentrations in plants grown in several greenhouse pot experiments, as affected largely by response to applied N and by continuing growth. Corn was grown in soil with 200 to 800 mg of N/pot and in nutrient solutions with 2 to 16 ppm of N. Both crops were harvested at 4-day intervals. Spinach and mustard were grown in soil with several rates of N, P, and K, and tall fescue with 1.0 and 2.0 g of N/pot.

76:02I-010

FOLIAR CONTENTS OF SODIUM AND CHLORIDE ON CITRUS ROOTSTOCKS IRRIGATION WITH SALINE WATER.

Cerda, A., Caro, M., Fernandez, F.G., and Guillen, M.G.
Centro de Edafologia y Biologia Aplicada del Segura, Department of Fertility and Vegetal Nutrition, Murcia, Spain.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock Texas, August 16-20, 1976, p 155-164. 1 fig, 4 tab, 20 ref.

Descriptors: Saline water, Salinity, Irrigation, Irrigation effects, [illegible]ium, Chloride.

A greenhouse experiment was conducted with six citrus seedlings used as rootstock in containers filled with a calcareous soil. These seedlings were irrigated with water salinized differentially with NaCl. As the experiment progressed, the salinity levels of the water were increased except for the controls. The experiment was carried out over a period of 13 months under differential irrigation treatment. Leaf samples were collected 4 times during the experiment. Chemical analysis of the leaf samples revealed marked differences in Na and Cl content due to seedling variety, salinity level of irrigation water, and length of treatment period. Leaf samples from Sour Orange seedlings contained the highest concentration of Cl. Leaf samples from the Cleopatra Mandarin seedlings contained the least amount of Cl. Leaf samples from the Kinnow seedlings contained the highest amount of Na and those from the Sour Orange seedlings the least.

SECTION X

WATER CYCLE

EROSION AND SEDIMENTATION (GROUP 02J)

76:02J-001
EROSION OF SELECTED HAWAII SOILS BY SIMULATED RAINFALL,
Dangler, E.W., and El-Swaify, S.A.
Hawaii University, Department of Agronomy and Soil Science, Honolulu, Hawaii.
Soil Science Society of America Journal, Vol. 40, No. 5, p 769-773, September-October 1976. 2 fig, 6 tab, 12 ref. ARS-USDA 12-14-5001-19, 12-14-5001-40.

Descriptors: *Erosion, *Simulated rainfall, *Soil types, *Hawaii, Laboratory tests, Soils, Soil erosion, Erosion rates, Storms, Tropical regions, Runoff, Rainfall.

Erodibilities, or K values of the universal soil loss equation, were determined for ten soils, representing five soil orders, on the islands of Oahu and Hawaii. Two successive, simulated rainstorms were used, each with an approximate intensity of 6.35 cm/hour and duration of 2 hours. Values obtained covered the wide range from 0 to 0.60 metric tons/ha per metric erosion index x 0.00774 and, in most cases, were higher for the second (wet) than for the first (dry) storm. Erodibility values for cropped Oahu soils, belonging to four soil orders, ranged from 0 to 0.26 for dry storms and from 0.001 to 0.41 for wet storms. Values for volcanic ash soils on Hawaii, belonging to only two orders, had the considerably wider range of 0.08 to 0.60 for dry storms and 0.07 to 0.51 for wet storms. Three of these soils exhibited essentially the same erodibility for dry and wet conditions. Dry and wet values were combined to calculate a weighted mean erodibility for each soil based on the distributions of natural rainfall throughout the year at the test sites. The weighted erodibility of a soil at a given location was, in general, inversely related to the amount of natural precipitation at that location.

76:02J-002
EFFICIENCY OF NITROGEN, CARBON, AND PHOSPHORUS RETENTION BY SMALL AGRICULTURAL RESERVOIRS,
Gill, A.C., McHenry, J.R., and Ritchie, J.C.
Agricultural Research Service, United States Department of Agriculture, Sedimentation Laboratory, Southern Region, Department of Chemistry, Oxford, Mississippi.
Journal of Environmental Quality, Vol. 5, No. 3, p 310-315, July-September 1976. 6 tab, 29 ref.

Descriptors: *Nitrogen, *Carbon, *Phosphorus, *Reservoirs, Mississippi, Nutrients, Erosion, Sedimentation, Soils, Soil investigations.

Total N, total C, and readily available organic and inorganic P contents, and particle-size distributions were determined for samples of soil and sediments collected from three agricultural watersheds in north Mississippi. The total quantities of N, P, C, and clay accumulated in the sediments of each reservoir were calculated. These values were compared with those calculated from soil losses estimated by using the Universal Soil Loss Equation. The results showed considerable variation between the percentages of plant nutrients and of soil particles retained in the reservoirs. These reservoirs were highly effective in retaining eroded soil particles. However, the percentages of soil nutrients retained in the reservoir sediments were less than the percentages of retained soil particles.

76:02J-003
EFFECT OF PORE WATER PRESSURE ON SAND SPLASH,
Sloneker, L.L., Olson, T.C., and Moldenhauer, W.C.
United States Department of Agriculture, Agricultural Research Service, Morris, Minnesota.
Soil Science Society of America Journal, Vol. 40, No. 6, p 948-951, November-

December 1976. 5 fig, 3 tab, 8 ref.

Descriptors: *Pore water, Sands, Erosion, Raindrops, Rainfall.

We studied the effect of pore-water pressure and particle-size distributions on the amount of sand splash and on the instantaneous pressure changes within a packed sand core caused by single water drops falling on the surface. Both splash amounts and pore-water pressure changes were affected by particle size, pore-water pressure before drop impact, and by the direction of approach to the pore-water pressure equilibrium. Pore-water pressure increases from falling water drops were generally greater when equilibrium pressures were approached directly than when they were approached from minimum pressure. Sand splash was also generally greater when equilibrium pressure was approached directly.

76:02J-004
SPLASH EROSION OF PRIMARY PARTICLES AND AGGREGATES,
Kinnell, P.I.A.
Commonwealth Scientific and Industrial Research Organization, Sediment Transport Group, Division of Soils, P.O. Box 639, Canberra City, Australian Capital Territory 2601, Australia.
Soil Science Society of America Journal, Vol. 40, No. 6, p 966-968, November-December 1976. 1 fig, 1 tab, 3 ref.

Descriptors: *Erosion, Rainfall, Soils, Soil properties, Soil investigations, Soil tests, Precipitation.

The previously supposed similarity between primary particles and aggregates in resisting splash erosion was shown to be partially incorrect. Mathematical treatment of splash-cup data on which the earlier conclusion was based showed that for surfaces containing aggregates, the quantity of material lost per unit quantity of artificial rainfall varied with rainfall intensity; a result which contrasts to observations for primary particles.

76:02J-005
A PORTABLE RAINFALL SIMULATOR FOR ERODIBILITY AND INFILTRATION MEASUREMENTS ON REGGED TERRAIN,
Munn, J.R. Jr., and Huntington, G.L.
Klamath National Forest, 1215 South Main Street, Yreka, California.
Soil Science Society'of America Journal, Vol. 40, No. 4, p 622-624, July-August 1976. 1 fig, 1 tab, 17 ref.

Descriptors: *Erosion, *Infiltration, *Rainfall simulators, Rainfall-runoff relationships, Rainfall.

A portable rainfall simulator for field study of erosion potential and infiltration on mountainous terrain is described. Polyethylene tubes produce 3.2-mm drops which fall 2.5m onto a 61 by 61 cm plot. The maximum rainfall intensity is 23 cm/hour. A 16% intensity variation across the plot area was measured, but the variation between separate simulated storms was < 1% for identical intensity settings. The unit us suited to one man operation on slopes up to 60%.

76:02J-006
MINERALOGY AND RELATED PARAMETERS OF FLUVIAL SUSPENDED SEDIMENTS IN NORTHWESTERN OHIO,
Wall, G.J., and Wilding, L.P.
Guelph University, Department of Soil Science, Agricultural Canada, Ontario, Canada.
Journal of Environmental Quality, Vol. 5, No. 2, p 168-173, April-June 1976. 4 fig, 3 tab, 29 ref.

Descriptors: Suspended solids, Ohio, Sampling, X-ray diffraction, Mineralogy, Calcium carbonate, Water quality, Sediments, Fluvial sediments, Soil erosion, Erosion.

Stream water samples were collected weekly for 17 months at eight sampling sites in the Maumee River Basin to characterize the clay mineralogy of the suspended sediments and to determine the utility of mineralogy as a marker of the source (rural, urban, geologic) of the sediments. X-ray diffraction analysis of the clay-sized sediments indicated little seasonal or downstream variability in clay mineral composition. The quantities of mica, quartz, and vermiculite-chlorite were 36 ± 5%, 29 ± 5%, and 20 ± 5%, respectively. The quantities of expandables, interstratified, and kaolinite minerals were usually < 10%. The cation exchange capacity (CEC), amorphous, fine clay, and organic matter content of the clay-sized suspended sediments were approximately 44 meq/100 g, 4.4%, 25%, respectively. Carbonate minerals were not detected in the clay-sized fraction. The 2 to 50 micro m fraction was dominated by quartz in high flow periods and secondary calcite in low flow periods. The stream water was calculated to be saturated with calcium carbonate, thus calcite precipitation could be expected.

76:02J-007
EROSION FOR CORN TILLAGE SYSTEMS,
Siemens, J.C., and Oschwald, W.R.
Illinois University at Urbana-Champaign, Department of Agricultural Engineering, Urbana-Champaignm Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 69-72, January-February 1976. 3 fig, 6 tab, 14 ref.
(See 76:03F-022)

76:02J-008
THE USE OF MULTIPLE REGRESSION MODELS IN PREDICTING SEDIMENT YIELD,
Weber, J.E., Gohrl, M.M., and Duckstein,L.
Arizona Univerisity, Deptarment of Management. Tucson Arizona.
Water Resources Bulletin, Vol. 12, No.1, p 1-17, February 1976. 9 fig, 4 tab, 9 ref.

Descriptors: *Sediment yield, *Regression analysis, *Model studies, *Watershed management, *Analytical techniques, Design, Erosion, Particle size, Soil types, Statistics.

Four commonly used models for predicting sediment yield were analyzed and compared using previously published data. Three of these models involved logarithmic transformations. Some of the problems involved in transforming data were discussed in the context of logarithmic transformations. The test data pertained to 39 watersheds in 11 western states, varying in size from a few acres to more than 50 square miles. Slope erosion is the only major sediment source in these watersheds. Standard regressions using the four models and test data illustrated the problems that may be caused by transformations. The standard regresssion analysis and the economic loss function for predicting sedimetn yields. If any transformation is made to satisfy the normality assumptions of linear regression analysis, it should be determined from the distribution of the sample residuals.

76:02J-009
TRIPOLYPHOSPHATE AND PYROPHOSPHATE HYDROLYSIS IN SEDIMENTS,
Blanchar, R.W., and Riego, D.C.
Monsanto Philippines Incorporated, Makati, Philippines
Soil Science Society of America Journal, Vol. 40, No. 2, p 2250229, March-April 1976. 3 fig, 2 tab, 22 ref.

Descriptors: Sediments, Sedimentation, Hydrolysis, Phosphate, Phosphorus, Nutrients.

The rate of hydrolysis of tripolyphosphate (TPP) and pyrophosphate (PP) in river, creek, and lake sediments was determined. Half-lives for the hydrolysis of TPP and PP ranged from 1.6 to 2.6 and 6.7 to 27.4 days, respectively. The influence of temperature, biological activity, and pH on the rate of TPP and PP hydrolysis was investigated using Flat Branch Creek sediment. The rate of TPP and PP hydrolysis increased with increasing temperature. The activation energy was 5.415 cal/mole for TPP and 10,412 cal/mole for PP. TPP and PP hydrolyzed slower in sedimetn which had been autoclaved than in non-sterlized sediment. The half-life for TPP hydrolysis was 1.76 day at pH 5, 1.61 day at pH 7, and 2,16 day at pH 9. The rate of PP hydrolysis was increased as pH increased as pH increased from 5 to 7 to 9 as indicated by half-lives of 13,7, 10.0, and 7.3 days, respectively. When TPPwas added to the sediment as a Ca5-

$(P_3O_{10})_2$ precipitate, the rate of hydrolysis was slower than when TPP was added as a solution.

76:02J-010
SEDIMENT YIELD-RUNOFF-DRAINAGE AREA RELATIONSHIPS IN THE UNITED STATES,
Dendy, F.E., and Bolton, G.C.
Agricultural Research Service, Sedimentation Laboratory, Oxford, Mississippi.
Journal of Soil and Water Conservation, Vol. 31, No. 6, p 264-266, November-December 1976. 5 fig, 1 tab, 11 ref.

Descriptors: *Sediment yield, *Watersheds (Basins), *Drainage area, Reservoirs, Mathematical studies, Analytical techniques, Statistical methods, Regression analysis, Equations, Runoff, Annual, Large watersheds, Small watersheds.

Watershed sediment yields, as determined from sediment deposits in about 800 reservoirs, were related to drainage area size and mean annual runoff. Average sediment yields per unit of net drainage area were inversely proportional to the 0.16 power of drainage area. Average sediment yields increased sharply to about 1,860 tons per square mile of drainage area as runoff increased from 0 to about 2 inches, and then decreased as runoff increased from 2 to about 50 inches.

76:02J-011
USE AND MISUSE OF THE UNIVERSAL SOIL LOSS EQUATION,
Wischmeier, W.H.
Purdue University, Department of Agricultural Engineering, Lafayette, Indiana.
Journal of Soil and Water Conservation, Vol. 31, No. 1, p 5-9, January-February 1976. 2 fig, 10 ref.

Descriptors: *Soil erosion, *Equations, *Erosion control, *Farm management, *Runoff, *Soil conservation, Sheet erosion, Sediment yield, Soil types, Rill erosion.

The universal soil loss equation was designed to predict soil loss from sheet and rill erosion. Variables affecting this erosion are grouped under six major erosion factors related to erosive forces of rainfall and runoff, inherent erodibility of a particular soil, shape and slope characteristics of the field, farm practices, and land management. The relation of a particular factor to soil loss is often appreciably influenced by the levels at which other factors are present. Computed soil loss is the best available estimate rather than an absolute value. The soil loss equation can be used to predict average annual soil movement to guide the selection of suitable conservation practices, to estimate the comparative utility of cropping systems, to determine optimum level of cropping and maximum tolerable slopes, and to provide soil loss data for erosional control needs. The researcher has to exercise judgment in selecting pertinent factor values that will account for differences from averages and for differences from field conditions and normal field operations.

76:02J-012
IMPROVED IMAGE-WELL TECHNIQUE FOR AQUIFER ANALYSIS,
Chan, Y.K.
Birmingham University, Department of Civil Engineering, (England)
Journal of Hydrology, Vol. 29, No. 1/2, p 149-164, March 1976. 10 fig, 3 tab, 7 ref, 1 append.

Descriptors: *Aquifers, *Pumping, *Boundaries (Surfaces), *Drawdown, *Methodology, Theis equation, Analytical techniques, Observation wells, Hydraulics.

The conventional image-well method does not yield accurate values of drawdown at large values of elapsed time since the commencement of pumping, when the number of images required becomes too large from the computational point of view. A reduction in error can be achieved by selecting an alternative image pattern; the actual form of the pattern depends on the particular boundary conditions. This improved image-well method involves a rearrangement of the image pattern. It overcomes the inherent uncertainty of the conventional method of images as to whether the number of images used is adequate to include a particular range of time. The improved method was tested at length by considering particular exmaples for nonleaky and leaky aquifers with fully-penetrating constant-discharge wells. Recommendations were made for a more efficient method of evaluating the integral form of the well functions.

76:02J-013
SUSPENDED SEDIMENT FILTRATION CAPACITY OF SIMULATED VEGETATION,
Tollner, E.D., Barfield, B.J., Haan, C.T., and Kao, T.Y.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 678-682, Special Edition 1976. 5 fig, 2 tab, 15 ref.

Descriptors: Sediments, Sedimentation, Vegetation, Vegetation effects, Sediment control, Open channel flow, Open channels.

An exponential power function relating the fraction of sediment in a simulated rigid vegetal media to pertinent physical variables was developed using linear regression techniques and various transformations. Homogeneous sediments and nonsubmerging flows were studied. The mean velocity was found to be the most influential parameter on sediment trapping followed by the flow depth, particle fall velocity, section length, and spacing hydraulic radius. The spacing hydraulic radius is a combination of the distance between two media elements and depth of flow and is analogous to the hydraulic radius of an open rectangular channel. This term was observed to be a reasonably good predictor of the length scale in shalle flows through the experimental media. An equation similar in form to Manning's equation utilizing the spacing hydraulic radius was observed to be a good predictor of the mean flow velocity.

76:02J-014
PREDICTING PARTICLE-SIZE COMPOSITION OF ERODED SOIL,
Young, R.A., and Onstad, C.A.
Agricultural Research Service, United States Department of Agriculture, Department of Agricultural Engineering, Morris, Minnesota.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1070-1075, Special Edition 1976. 2 fig, 3 tab, 22 ref.

Descriptors: *Particle size, Erosion, Organic matter, Pore pressure, Soils, Soil investigations, Sediments.

A set of equations was developed for predicting particle-size distribution of eroded soil, based on soil surface area and texture and considering organic matter enrighment and the tendency of a soil to rill. Three parameters--particle-size distribution of the matrix soil, organic matter, and water content at -15 bars pore pressure gave a good estimate of the expected particle-size distribution.

76:02J-015
CORN-SOYBEAN TILLAGE SYSTEMS: EROSION CONTROL, EFFECTS ON CROP PRODUCTION, COSTS,
Siemens, J.C. and Oschwald, W.R.
Illinois University, Department of Agricultural Engineering, Urbana, Illinois.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 30 p, 7 fig, 23 tab, 12 ref.

Descriptors: Erosion, Erosion runoff, Crop production, Corn, Soybeans, Soil erosion, Economics.

Seven tillage systems for producing corn and soybeans were compared in terms of erosion control, effects on crop rpoduction, and cost. Conservation tillage systems greatly reduced soil erosion. Yields were sometimes less with conservation tillage. Total costs for the different systems were equivalent. (Skogerboe-Colorado State)

76:02J-016
TWO-DIMENSIONAL MODEL OF EROSION FROM A WATERSHED,
Kuh, H-c, Reddell, D.L., and Hiler, E.A.
Texas A and M University, Department of Agricultural Engineering, College Station, Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 26 p, 3 fig, 2 tab, 6 ref.

Descriptors: Model studies, Simulation analysis, Sediments, Sedimentation, Erosion, Watersheds, Watershed management.

A two-dimensional model of erosion from a small watershed is described. The model provides estimates of the amount of sediment eroded from a watershed plus the areal distribution of erosion or deposition on the watershed. Predicted values are compared with measured data from individual storms over an 11-year period with excellent agreement. Results are also compared with estimates of erosion made by the original and modified versions of the Universal Soil Loss Equation.

76:02J-017
EFFECTS OF DESIGN FACTORS SEDIMENTATION BASIN PERFORMANCE,
Pennell, A.B., and Larson, C.L.
Minessota Department of Natural Resources, St. Paul, Minnesota.
Paper No 76-2020, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976, Lincoln, Nebraska, 6 fig, 26 ref.

Descriptors: Sedimentation, Model studies, Simulation analysis, Mathematical studies, Sediments, Sediment control.

A mathematical model designed to evaluate sedimentation basin performance as affected by variations in design factors produces trap efficiency curves showing that, beyond capacity, the most significant factors are basin depth and length of detention time. In field application, these factors take on a higher degree of significance in the ability of the user to manipulate them as required by site-specific conditions and trap efficiency goals. Figures 3-6 reflect the relationship of variations in these factors in obtaining a desired output. The results obtained are limited in that they are based on a mathematical model developed with certain assumptions described earlier. Also, data were not available for testing the model. Accordingly, the absolute values as presented may be somewhat in error. However, the comparative values and the relative effects should be reliable.

SECTION XI

WATER CYCLE

CHEMICAL PROCESSES (GROUP 02K)

76:02K-001
CALCIUM RETENTION IN RESPONSE TO PHOSPHATE SORPTION BY SOILS,
Ryden, J.C., and Syers, J.K.
Massey University, Department of Soil Science, Palmerston, North, New Zealand.
Soil Science Society of America Journal, Vol. 40, No. 6, p 845-846, November-December 1976. 1 tab, 8 ref.

Descriptors: *Sorption, Desorption, Precipitation, Calcium, Potassium, Soil chemistry, Soil investigations.

Retention of Ca increased in response to P sorption by soils, but was independent of the amounts of added Ca. Rather constant values were obtained for the molar ration of Ca/P retained (0.19 to 0.34). Retained Ca was essentially recovered in 1M KCl washings in contrast to the fractional recovery of sorbed P. The retention of Ca in response to P sorption by soils is interpreted as arising from the increase in negative charge induced by P sorption.

76:02K-002
ADSORPTION OF SELENITE AND PHOSPHATE ON AN ALLOPHANE CLAY,
Rajan, S.S.S., and Watkinson, J.H.
Ruakura Agrucultural Research Center, Soil Chemistry Group, Hamilton, New Zealand.
Soil Science Society of America Journal, Vol. 40, No. 1, p 51-54, January-February 1976. 3 fig, 3 tab, 20 ref.

Descriptors: *Adsorption, *Clays, *Sulfate, *Phosphate, Soils, Soil investigations, Soil properties, Soil chemistry, Anions, Anion adsorption.

Selenite was adsorbed on an allophane clay from solutions of different concentrations at pH 5.0, at 30C, and under a N2 atmosphere, and the amounts of sulfate, silicate and hydroxyl ions released were measured. The results were compared with those from a similar study with phosphate on the same clay. The results indicate that at low concentrations both phosphate and selenite exchanged with adsorbed sulfate, adsorbed silicate, and aquo and hydroxo groups. About three times more phosphate than selenite was adsorbed, due mainly to phosphate displacing more aquo groups and thus making the surface less positive. At high concentrations, whereas the selenite adsorption reached a maximum, phosphate continued to be adsorbed. The latter was due to phosphate displacing structural silicate and probably also to disruption of hydrous oxide polymers. A two-term Langmuir equation distinguished adsorption by surface ligand exchange exchange from these other reactions at high concentration.

76:02K-003
CHEMICAL REDUCTION OF NITRATE BY FERROUS IRON,
Buresh, R.J., and Moraghan, J.T.
North Dakota State University, Department of Soils, Fargo, North Dakota.
Journal of Environmental Quality, Vol. 5, No. 3, p 320-325, July-September 1976. 5 fig, 4 tab, 30 ref.

Descriptors: *Nitrates, *Denitrification, *Nitrogen, Chemical reaction, Chemicals.

Knowledge concerning the chemical reduction of NO3(-) to gaseous products, a process of potential practical significance as an antipollution device, is sparse. The influence on pH on chemical reduction of NO3(-)-N (approximate concentration 23 ppm) by Fe(2+) in the presence and absence of Cu(2+) was studied over a pH range from 6 to 10. After 24-hours of controlled pH incubations under a helium atmosphere NO3(-), N2O, NO, N2, and NH4(+) were determined. The initial Fe(2+)/NO3(-) mole ratio was 8. Reduction of NO3(-) was negligible in the absence of

Cu(2+), but was pronounced above pH 7 in the presence of approximately 5 ppm Cu(2+). Formation of NH4(+) increased with pH and was the dominant process at pH 9 and 10. Nitrous oxide and N2 accumulations were greatest in the pH range from 8 to 8.5 and negligible at pH 6 and 10. Nitrite formation was small except at pH 9 and 10. Trace quantities of NO accumulated during incubation if the pH was allowed to drop below 6. Levels of Cu(2+) and Fe(2+) influenced the extent and nature of NO3(-) reduction at pH 8. Maximum reduction of NO3(-) (93%) and maximum gas production (equivalent to 61% of the original NO3(-) occurred when the Fe(2+)/NO3(-) mole ratio was 12 and the Cu(2+) level was approximately 10 ppm. The N2O/N2 mole ratio in the evolved gases decreased as the Cu(2+) level was increased from approximately 1 to 10 ppm and as the Fe(2+)/NO3(-) mole ratio was increased from 8 to 12. Nitrate was relatively stable at a Cu(2+) content of 0.1 ppm irrespective of the Fe(2+)/NO3(-) ratio.

76:02K-004
HETEROVALENT CATION EXCHANGE EQUILIBRIA IN SOILS WITH VARIABLE AND HETEROGENEOUS CHARGE,
Munns, D.N.
California University, Department of Soil Science, Davis, California.
Soil Science Society of America Journal, Vol. 40, No. 6, p 841-845, November-December 1976. 4 fig, 1 tab, 15 ref.

Descriptors: *Cation exchange, *Leaching, Soil properties, Soil investigations, Calcium, Magnesium, Lime.

Divalent cations were incrementally displaced, from limed and un-limed samples of three soils, by suspending the soils in increasing volumes of 2mM KCl. Mass action coefficients for exchange between Ca and Mg were constant. But for the exchange of divalent cations by K, the exchange coefficients of Kerr, Vaneslow, Gapon, Krishnamoorthy and Overstreet, and Gaines and Thomas increased markedly as potassium saturation or pH increased. For each cation species, separate fractions which were relatively loosely adsorbed could be estimated by a simple regression analysis. The loosely adsorbed Ca, which may control Ca availability to plants, could be independently estimated by a leaching procedure. Mass action exchange coefficients for the loosely adsorbed cations were approximately constant under all conditions tested. The variable charge mobilized by liming differed from the fixed charge in having a slightly higher proportion of sites with high divalent affinity, in an Oxisol, and a much lower proportion in a Vertisol and a Mollisol.

76:02K-005
BEHAVIOR OF CHROMIUM IN SOILS: TRIVALENT FORMS,
Bartlett, R.J., and Kimble, J.M.
Vermont University, Department of Plant and Soil Science, and Vermont Agricultural Experiment Station, Burlington, Vermont.
Journal of Environmental Quality, Vol. 5, No. 4, p 379-383, October-December 1976. 2 fig, 4 tab, 9 ref.

Descriptors: *Aluminum, *Chromium, Field capacity, Soils, Soil investigations, Adsorption, Phosphorus, Chemical reactions.

Chemical behavior of Cr(III) was studied in solutions, soil suspensions, and in soils of contrasting characteristics incubated at field capacity moisture. Sodium pyrophosphate, pH 4.8 NH4OAc, and 0.1 M NaF appeared to extract organically bound Cr(III), whereas 1M HCl removed inorganic Cr hydroxides and phosphates along with some organic Cr. Pyrophosphate and HCl extracts represented quantities of Cr(III) removed; NH4OAc and NaF extracts appeared to characterize small readily removed fractions, that is, intensity factors. Soil organic complexes of Cr(III) formed at low pH and appeared to remain stable and soluble even when soil pH's were raised to levels where the Cr would be expected to precipitate. Adsorption and solubility behavior of Cr(III) as it varied with pH and P treatments was similar to that of Al. Oxidation of Cr(III) to Cr(VI) was not demonstrated at all, even under conditions of maximum aeration and high pH.

76:02K-006

BEHAVIOR OF CHROMIUM IN SOILS: II. HEXAVALENT FORMS,

Bartlett, R.J., and Kimble, J.M.
Vermont University, Department of Plant and Soil Science, and Vermont Agricultural Experiment Station, Burlington, Vermont.
Journal of Environmental Quality, Vol. 5, No. 4, p 383-386, October-December 1976. 2 fig, 4 tab, 7 ref.

Descriptors: *Chromium, *Adsorption, Organic matter, Soils, Soil investigation, Farm wastes, Aluminum, Phosphorus.

Adsorption and reduction of added Cr(VI) were characterized in soils with contrasting pH's, organic matter contents, and chemical and mineralogical properties. Presence of soil organic matter brought about spontaneous reduction of Cr(VI) to Cr(III), even at pH's above neutrality. Reduction did not occur in soils very low in organic matter unless an energy source was added. Cow manure added to practically organic-free Cecil B2 reduced Cr(VI) only after the pH had been lowered below 3 with HCl. The solubility of Cr(VI) in the presence of excess Al changed in a pattern remindful of orthophosphate. All of the soils, except a pH 7.8 Cca horizon material, adsorbed Cr(VI). Presence of orthophosphate prevented the adsorption of Cr(VI), presumably by competition for the adsorption sites. Consistent with this finding, KH2PO4 was found to be the best extracting agent for Cr(VI). It was concluded that behavior of Cr(VI), if it remains in soils, is similar to that of orthophosphate. However, unlike phosphate, Cr(VI) is quickly reduced by soil organic matter. Thus, Cr(VI) added to a soil will remain mobile only if its concentration exceeds both the adsorbing and the reducing capacities of the soil.

76:02K-007

MICROBIAL INORGANIC POLYPHOSPHATES: FACTORS INFLUENCING THEIR ACCUMULATION,

Pepper, I.L., Miller, R.H., and Ghonsikar, C.P.
Ohio Agricultural Research and Development Center.
Soil Science Society of America Journal, Vol. 40, No. 6, p 872-875, November-December 1976. 2 fig, 5 tab, 8 ref.

Descriptors: *Phosphorus, Soil chemistry, Soil properties, Soil investigations.

Infrared spectra of microbially synthesized, acid labile, inorganic P compounds extracted from soils provided additional evidence that they are inorganic polyphosphates (poly P). Incubation studies with glucose amended soils demonstrated the transient nature of naturally occurring poly P. Experiments are reported on the conditions which optimize poly P synthesis in soil. A 2-week incubation period (preincubation) with a source of carbon (2% glucose or 4% straw) and a further 2-day incubation period (postincubation) after adding a source of ortho P resulted in the maximum accumulation of poly P. The quantity of poly P also increased with increasing rates of orthophosphate from none to 1,000 micro g soil/g. Longer periods of postincubation reduced poly P accumulation. Poly P synthesis was greater when relatively insoluble sources of P were added to soils and accumulation followed the order; FePO4 . 2H2O > rock phosphate > Ca(H2PO4)2 . H2O > KH2PO4. The results suggest that poly P synthesis may accompany P solubilization in soils and be an integral part of the soil P cycle.

76:02K-008

THE SLOW REACTION WHICH CONTINUES AFTER PHOSPHATE ADSORPTION: KINETICS AND EQUILIBRIUM IN SOME TROPICAL SOILS,

Munns, D.N., and Fox, R.L.
California University, Department of Soils and Plant Nutrition, Davis, California.
Soil Science Society of America Journal, Vol. 40, No. 1, p 46-51, January-February 1976. 7 fig, 2 tab, 18 ref.

Descriptors: *Phosphate, *Top soil, Adsorption, Soils, Soil investigations, Kinetics, Lime, Hysteresis, Soil properties, Soil chemestry.

Dissolved phosphate was mixed with topsoil samples, and the decline in solution phosphate concentration (P) was followed for 200-300 days by periodically shaking and extracting subsamples with 1 or 10 mM CaCl2. During the first 20-40 days, (P) declined faster in soil suspensions that were being shaken than it did in undisturbed soil at 0.1 bar moisture. After 40 days of reaction, shaking time had little effect. The slow fixation had first-order kinetics with respect to (P). The relative rate was faster in an Andept than in three Oxisols. It was unaffected by lime, though lime increased the strength of adsorption. Equilibrium was achieved at 50 days in an Andept and 100-200 days in three Oxisols. At equilibrium, the amount of adsorbed phosphate remaining labile was estimated from values of (P), using 6-day adsorption isotherms. Labile phosphate so estimated amounted to 30 to 50% of the added phosphate, implying that the residual value of phosphate added to these soils should be substantial and permanent except for removal by crops and erosion. Desorption isotherms diverged from adsorption isotherms less markedly with increasing time after phosphate addition, as if the slow reaction caused much of the apparent hysteresis.

76:02K-009
ADSORPTION OF DODECYLBENZENE SULFONATE ON NA(+)-MONTMORILLONITE: EFFECT OF SALT IMPURITIES,
Clementz, D.M., and Robbins, J.L.
Chevron Oil Field Research Company, La Habra, California.
Soil Science Society of America Journal, Vol. 40, No. 5, p663-665, September-October 1976. 1 fig, 12 ref.

Descriptors: Adsorption, Montmorillonite, Surfactants, Anion exchange, Clays, Salt.

The adsorption of purified dodecylbenzene sulfonate (ABS) on Na(+)-montmorillonite follows the Langmuir isotherm, reaching a maximum amount adsorbed which corresponds to the anion exchange capacity fo the clay. When a commercial grade ABS is used, the adsorption process is more complex and occurs in two distinct steps. In dilute solutions, the salt impurity has a minor effect on adsorption and the result is essentially the same as that obtained for the purified surfactant. However, as the salt concentration is increased to a given value, enhanced adsorption due to hemimicelle formation occurs.

76:02K-010
INFLUENCE OF IONIC STRENGTH AND INORGANIC COMPLEX FORMATION ON THE SORPTION OF TRACE AMOUNTS OF CD BY MONTMORILLONITE,
Garcia-Miragayma, J., and Page, A.L.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California.
Soil Science Society of America Journal, Vol. 40, No. 5, p 658-663, September-October 1976. 5 fig, 3 tab, 20 ref.

Descriptors: Cadmium, Sorption, Montmorillonite, Clays, Soils, Soil investigations, Soil chemistry, Heavy metals.

Cadmium sorption by montmorillonite from solutions in the 15 to 120 ppb range was studied in the presence of increasing concentrations of NaClO4, NaCl, and Na2SO4 solutions. The ionic strengths ranged from 0.01 to 1.00. Increasing ionic strengths decreased the amount of Cd sorbed on the clay surfaces. The percentage sorbed decreased from around 90% for I=0.01 to about 50% for I=1.00 in the ClO4 systems. The sorption of Cd in the chloride system was in the range between 25 to 50% less than the ClO4 systems for the same ionic strength. This was attributed to the presence of uncharged and negatively charged complexes of Cd with Cl ligands. This fact has some implications, especially in arid zone soils where high Cl concentrations in soil solutions are not unusual; there, Cd will behave mainly as a neutral species (CdCl2(0)) and as an anion (CaCl3(-) and CdCl4(2-)), rather than as a cation (Cd(2+)). The SO4 systems showed a moderate decrease in the amount of Cd sorbed with respect to the ClO4 systems for the same salt concentrations. This observation was interpreted as due to the presence of a fraction of Cd in solution as the CdSO4(0) species.

76:02K-011
ESTIMATING WATER SALINITY WITH GEOPHYSICAL EARTH RESISTIVITY EQUIPMENT,
Halvorson, A.D., and Reule, C.A.
Agricultural Research Service, Sidney, Montana.
Soil Science Society of America Journal, Vol. 40, No. 1, p 152-153, January-February 1976. 2 fig, 1 tab, 5 ref.
(See 76:07B-003)

76:02K-012
ATMOSPHEREIC INPUT OF SOME CATIONS AND ANIONS TO FOREST ECOSYSTEMS IN NORTH CAROLINA AND TENNESSEE,
Swank, W.T., and Henderson,G.S.
United States Department of Agriculture, Forest Service, Coweeta Hydrologic Laboratory, Franklin, North Carolina.
Water Resources Research, Vol.12, No. 3, p 541-546, June 1976. 3 fig, 2 tab. 23 ref.

Descriptors: Chemical properties, *Fallout, *Precipitation(Atmosphereic), *Appalachian mountain region, *Forest watersheds, *North Carolina, *Tennessee, *Southeast U.S., Rain, Forests, *Cations, On-site data collections, *Atmosphere, Seasonal.

The atmospheric contributions of elements in precipitation and dry fallout to forest ecosystems were measured at two sites in the southern Applachians. At both sites, relative mean annual concentrations of cations in bulk precipitation were in the order Ca is greater than Na is greater than K is greater than Mg. At the Coweeta Hydrologic Laboratory in North Carolina, average annual inputs of Ca(++), Na(+),K(+), Mg(++), and NH4-N in 1970-1973 were 4,88, 3.52, 1.62, 1.01, and 0.52 kg/ha/yr, respectively. At Walker Branch, Tennessee, the inputs of these elements during the same time period were 15.73, 3.89, 2.99, 2.94, and 2.37 kg/ha/yr. The inputs of NO3-J, PO4-P, and C;(-), in 1972-1973 were 2.88, 0.19, and 8.53 kg/ha/yr at Coweeta. Inputs of NO3-N, and PO4-P were 4.61 and 0.55 kg/ha at Walker Branch over the same period. One reason for differences in bulk precipitaion chemistry was greater dry fallout for some cations at Walker Branch than at Coweeta. For both sites, dry fallout associated concentrations of bulk precipitation except for Na(+), which appeared to be partly derived from marine sources. Total inputs of elements were considered to be minimum estimates for both forest ecosystems due to sampling and analytical methods.

76:02K-013
PHOSPHOROUS SORPTION AND DESORPTION CHARACTERISTICS OF SOIL AS AFFECTED BY ORGANIC
Singh, B.B., and Jones, J.P.
Idaho University, Department of Plant and Soil Sciences, Moscow, Idaho
Soil Science Society of Amercia Journal, Vol. 40, No, 3, p 389-394, May-June 1976. 7 fig, 1 tab, 31 ref.

Descriptors: *Phosphorous, *Sorption, Organic matter, Soils, Soil investigations, Soil properties, Alfalfa, Beans, Barley, Farm Waste, Mineralization.

The influence of seven organic residues on sorption and desorption of P by a high P-fixing soil was determined after 30, 75, and 150 days incubation. After incubation for 30 days, all residues decreased the amount of P sorbed by the soil, resulting in higher equilibrium solution P levels. However, after incubating for either 75 or 150 days, the P content of the organic residues had a marked influence on sorption of added P and desorption of sorbed P. The critical value of P in organic residues which resulted in no tie-up of soil P was 0.3%. Sawdust, wheat straw, and cornstalks contained < 0.3% P decreased labile soil P and increased sorption by soil after incubating for 75 or 150 days. Alfalfa, barley, beans, and poultry manure that contained P in excess of 0.3% decreased sorption of P. The results suggest that P fertilizer rates estimated from sorption isotherms may need to be modified following addition of organic residues.

76:02K-014
INFLUENCE OF SOIL PH ON THE AVAILABILITY OF ADDED BORON,
Peterson, L.A., and Newman, R.C.
Wisconsin University, Departments of Horticulture and of Soil Science, Madison, Wisconsin.
Soil Science Society of America Journal, Vol. 40, No. 2, p 280-282, March-April 1976. 1 fig, 3 tab, 13 ref.

Descriptors: *Boron, Fescue, Soil properties, Greenhouses, Soil chemistry, Soil investigations.

A Plano silt loam with five relatively constant pH levels (4.7, 5.3, 5.8, 6.3, 7.4) was used to study the influence of soil pH on the availability of added B. A greenhouse study was conducted using tall fescue with five soil pH levels, and four rates of applied B essentially equivalent to 0, 5, 10, and 20 kg/ha, and five herbage harvests. Herbage yields of tall fescue were not affected by either soil pH or B treatments: however, tissue B concentrations ranged from 8 to 739 ppm for the five harvests. Boron uptake by tall fescue was relatively uniform for soil pH levels of 4.7, 5.3, 5.8, and 6.3 within each level of B availability. Recovery percentages of 30 to 50% of the added B by five cuttings of forage indicate a soil fixation of B. Highest recovery percentage was associated with the highest rate of added B. A 2.5-fold drop in B uptake occurred at pH 7.4 as compared with the other soil pH levels indicating substantial fixation of B. Hot-water-soluble B content of the soil generally increased with an increase in pH and with added B. The soluble B test did not predict the low recovery of B at pH 7.4.

76:02K-015

AN EVALUATION OF JOB'S METHOD OF CONTINUOUS VARIATIONS AS APPLIED TO SOIL ORGANIC MATTER-METAL ION INTERACTIONS,

MacCarthy, P., and Mark, H.B. Jr.
Georgia University, Department of Chemistry, Athens, Georgia.
Soil Science Society of America Journal, Vol. 40, No. 2, p 267-276, March-April 1976. 5 fig, 31 ref.

Descriptors: Organic matter, Ions, Soil chemistry, Soil properties, Soil investigations, Metals, Absorption.

The literature dealing with the application of Job's method of continuous variations to the study of soil organic matter-metal ion interactions has been reviewed, and an introduction to the fundamental chemistry necessary for an understanding of these interactions is presented. The method of continuous variations was applied to simple systems consisting of metal ions and mixtures of discrete ligands. The behavior of these "model" systems was compared to that of the more complicated soil organic matter systems. Following a consideration of the fundamental principles of Job's method and of its boundary conditions and limitations, it was concluded that this method is not directly applicable to the study of soil organic matter-metal ion interactions. This conclusion was substantiated by experiments carried out on the simple "model" systems as well as those on fulvic acid itself. Explanations are proposed to account for the deceptive results which were obtained when this method was erroneously applied by other workers to the investigation of soil organic matter-metal ion interactions in the past. Possible interferences, due to scattering of light, during the study of soil organic matter-metal ion reactions by UV-visible absorption spectroscopy are considered.

76:02K-016

THE RELEASE OF NITROGEN FROM SULFUR-COATED UREA AS AFFECTED BY SOIL MOISTURE, COATING WEIGHT, AND METHOD OF PLACEMENT,

Prasad, M.
M.J. Woods and Associates, 13 Kilbarrack Grove, Dublin 5, Ireland.
Soil Science Society of America Journal, Vol. 40, No. 1, p 134-136, January-February 1976. 5 tab, 13 ref.

Descriptors: *Nitrogen, *Urea, *Soil moisture, Calcareous soil, Soil investigations, Nitrification, Nitrite, Volatility.

Information on the release of N from sulfur-coated urea (SCU) as affected by soil moisture in the aerated range is lacking. Laboratory incubation experiments were therefore conducted on two soil to study the release of N from SCU as affected by soil moisture in the aerated range, coating weight (SCU-28 and SCU-9), and method of placement (on one soil only). In the calcareous Princes Town soil the release of N from SCU increased with increasing moisture throughout the 9 weeks of study. In acid Talparo soil similar trends were present up to 3 weeks, but at 6 and 9 weeks maximum release of N occurred at medium soisture (soil moisture at pF 2.4) and minimum release at low moisture (soil moisture at pF 3.5).

76:02K-017

THEORETICAL CONSIDERATION ON NITRITE SELF-DECOMPOSITION REACTIONS IN SOILS,

Van Cleemput, O., and Baert, L.
Ghent University, Laboratory of Physical and Radiobiological Chemistry, Belgium.
Soil Science Society of America Journal, Vol. 40, No. 1, p 322-324, March-April 1976. 3 fig, 10 ref.

Descriptors: Soils, Soil investigations, Soil properties, Nitrite.

The spontaniety of different nitrous acid self-decomposition reactions was calculated for different sets of activities of the participating components at pH 4, 7, and 9. These calculations showed that nitrous acid preferentially decomposes spontaneously to NO and NO3(-) instead of self-decomposition to NO and NO2 or N2O4. The higher the pH the larger the region of nitrous acid stability. Theoretical evidence for the reaction of nitrous and nitric acid with formation of NO2 was obtained.

76:02K-018

INFLUENCE OF SALT AND ALKALI ON IONIC EQUILIBRIA IN SUBMERGED SOILS,

Pasricha, N.S., and Ponnamperuma, F.N.
International Rice Research Institute, Los Banos, Laguna, Philippines.
Soil Science Society of America Journal, Vol. 40, No. 3, p 374-376, May-June 1976. 4 tab, 15 ref.

Descriptors: Salt, Salinity, Alkali, Clays, Sodium, Sampling, Ions, Iron, Manganese, Soils, Soil investigations, Soil properties.

To clarify the effects of salt and alkali on Fe(2+) and Mn(2+) equilibria in submerged soils, Maahas clay (a Haplustalf) was amended with NaCl and NaHCO3 to give initial electrical conductivities of 5, 10, 20, and 25 mmhos/cm at 25C and exchangeable Na percentages of 5, 10, 15, 20, and 25, respectively. The amended soils and an untreated control were kept submerged in 16-liter pots in a greenhouse at 25-30C. The soil solutions, drawn anoxically by gravity, were analyzed fortnightly for Eh, pH, CO2, and the major ions. As the salt level increased, the concentrations of all cations except K(+) and Na(+) decreased. In spite of wide variations in pH, Eh, ionic strength, and the concentrations of Fe(2+) and Mn(2+) in the soil solutions, the values of the expressions, pE - pFe(2+) + 3 pH, pE - 1.5 pFe(2+) + 4 pH, pE + pH, and pH - 0.5 pMn(2+) - 0.5 pCO2 were nearly equal to 17.9, 23.3, 7.3, and 4.1, respectively, indicating that even in the salt and alkali treated soils, the Fe(OH)3 - Fe(2+) and Fe3(OH)8 - Fe(2+) systems controlled the solubility of Fe(2+) while the MnCO3 - H2) - CO2 system regulated the solubility of Mn(2+).

76:02K-019

ZINC ADSORPTION ISOTHERMS FOR SOIL CLAYS WITH AND WITHOUT IRON OXIDES REMOVED,

Shuman, L.M.
Georgia University, Department of Agronomy, Georgia Experiment Station, Athens, Georgia.
Soil Science Society of America Journal, Vol. 40, No. 3, p 349-352, May-June 1976. 2 fig, 3 tab, 16 ref.

Descriptors: *Zinc, *Adsorption, Georgia, Clays, Soils, Soil properties, Iron oxides, Soil investigations.

The clay fraction from four predominant Georgia Soils sampled at two depths was separated and the iron oxides removed from a portion of each clay sample. These clays were equilibrated with five Zn solutions to measure Zn adsorption. The data conformed to the Langmuir adsorption isotherm. Langmuir coefficients were used to evaluate the Zn adsorptive capacities of the clays and bonding energies for Zn. Adsorptive capacities and CEC values for the clays from Decatur cl and Leefield ls soils were higher than those for clays from the Cecil sl and Norfolk ls soils. Differences in adsorptive capacities were not consistent between depths nor between samples with or without Fe oxides. However, removal of the Fe oxides increased the capacity to adsorb Zn in more instances than it decreased this capacity. Zinc adsorptive capacities were directly related to the CEC values for the clays. When comparing those samples with and without Fe oxides removed, bonding energies were inversely related to adsorptive capacities.

76:02K-020
WASTEWATERS IN THE VADOSE ZONE OF ARID REGIONS: HYDROLOGIC INTERACTIONS,
Mann, J.F., Jr.
Ground Water, Vol. 14, No. 6, p 367-373, November-December 1976. 6 fig, 12 ref.

Descriptors: *Waste storage, *Waste water disposal, *Arid lands, *Vadose water, *Nevada, Groundwater recharge, Evapotranspiration, Soil water, Water table, Moisture content, Field capacity, Pollutants, Soil water movement, Infiltration, Leachate, Nuclear meters, Clays, Storage, Monitoring.

In truly arid regions there is essentially no direct penetration of rainfall. Such water is quickly dissipated by capillarity-assisted evaporation or through rapid evapotranspiration by short-lived annuals. Where perennial xerophytes cover the ground surface, the extensive shallow root systems quickly utilize all of the rainfall stored in the soil. Beneath the soil zone is the lower part of the vadose zone, extending to water tables at depths of tens to hundreds of feet. Almost always these vadose zones have moisture contents well below field capacity. Regardless of the cause, these dry vadose zones are capable of holding additional water, at least up to field capacity. And no water-carried pollutants can reach the water table from the ground surface until a pre-wetted path has been formed for the entire vertical distance. A practical use of this water-holding capacity can be made in the design of wastewater tailings ponds, with predictable safety and with great economic benefit. However, only in predictable geologic conditions, and in limited amounts can the use of this water-holding capacity be recommended. On the other hand, to make no use whatsoever of these great natural dry sponges would be an economic waste.

76:02K-021
DENITRIFICATION MEASURED DIRECTLY FROM NITROGEN AND NITROUS OXIDE GAS FLUXES,
Rolston, D.E., Fried, M., and Goldhamer, D.A.
California University, Department of Land, Air, and Water Resources, Davis, California 95616
Soil Science Society of America Journal, Vol. 40, No. 2, p 259-266, March-April 1976. 8 fig, 2 tab, 17 ref.

Descriptors: Denitrification, Nitrogen, Fertilization, Soils, Soil water, Lysimeters, Diffusion, Leaching.

The amount of denitrification is generally the unknown in attempts to evaluate the fate of N fertilizers applied to soils. Substantial error can result when denitrification is determined from the difference between measurements of plant uptake, residual soil N, leaching, and the amount of N applied. An independent, direct measure of denitrification potentially has merit by containing [illegible] the error from direct measurement and not a cumulative error from several [illegible]urements. Nitrate at a rate of 300 kg of N/ha and enriched with 20 and 10 atom percent excess N-15 was applied to laboratory columns and a field plot, respectively. The columns were maintained at soil-water pressure heads of -22 and -70 cm. The field plot was maintained at a soil-water pressure head of approximately -10 cm in the upper 10 cm of soil. The field plot was cropped with perennial ryegrass. The columns and field plot were instrumented with tensiometers, soil solution samplers, and gas samplers. The concentration and isotopic ratio of NO3, N2, and N2O were measured as a function of soil depth and time. The gaseous concentration gradients and measured apparent diffusion coefficients were used to calculate the fluxes of (N-15)2 and (N-15)20 gas from the soil. Residual soil N, plant uptake, and leaching were measured in order to calculate denitrification by difference. For the laboratory columns, the amount of denitrification determined directly compared favorably with that determined by difference.

SECTION XII

WATER CYCLE

ESTUARIES (GROUP 02L)

76:02L-001
PARTIAL DEPLETION OF SALINE GROUNDWATER BY SEEPAGE,
Van Dam, J.C.
Technische Hogeschool, Department of Civil Engineering, Delft, (Netherlands).
Journal of Hydrology, Vol. 29, No. 3/4, p 315-339, April 1976. 14 fig, 3 tab, 4 ref.

Descriptors: *Saline water intrusion, *Encroachment, *Saline water systems, *Hydrogeology, *Seepage, *Model studies, Land reclamation, Water table, Pumping, Freshwater, Recharge, Saline water, Groundwater.

The geohydrologic conditions prevailing in the western part of the Netherlands, particularly the numerous so-called polders, were analyzed with respect to seepage of saline water. The polders are reclaimed lakes or parts thereof and have a land elevation of up to several meters below mean sea level. The groundwater levels in the polders are artificially controlled at depths of about 0.3 to 2 meters below land surface by means of embankments, sluices, and pumping stations. A highly schematized, one-dimensional model was developed to investigate the effects of reclamation of the deep polders. Seepage of saline water induced by reclamation of these polders was found to be of temporary nature. This temporary seepage comes from diminution of the volume of saline water present in the aquifer. The permanent seepage of saline water, currently recharged by sea water, increases with lower polder levels. The results of this model study indicated interesting tendencies, but more complicated models and study of transient effects are needed to interpret the actual field conditions.

SECTION XIII

WATER SUPPLY AUGMENTATION AND CONSERVATION

SALINE WATER CONVERSION (GROUP 03A)

76:03A-001
THE INTEGRATION OF DESALINATION PLANT WITH EXISTING AUSTRALIAN WATER RESOURCES,
Kemeny, L.G.
New South Wales University, School of Nuclear Engineering, Kensington
(Australia).
Journal of Hydrology (Amsterdam), Vol. 28, No. 2/4, p 429-448, 1976. 8 fig,
4 tab, 14 ref, 2 append.

Descriptors: *Desalination plants, *Water resources, *Australia, *Water supply, Water utilization, Arid lands, Coasts, Economics, Hydrologic aspects, Salinity, Freshwater, Water storage, Water distribution (Applied), Costs, Size sites, Energy.

Two-thirds of Australian land is arid; even the well-watered coastal areas are prone to prolonged droughts. Thus, the capital investment in water supply storage and distribution facilities is very high. These economic and ecological conditions demand alternative sources of fresh water supplementation, probably desalination. A summary of Australian water resources is given, including geographical distribution of surface discharge and runoff, typical salinities of underground waters, and permissible limits of salinity. Considered next are the patterns of fresh water usage and the related costing practice; these are subdivided into domestic, industrial and agricultural supplies. A description of an existing desalination plant on the Western Australian Coast is given. Finally general factors influencing the integration of desalination plant with existing water resources in Australia are summarized; discussed are water storage and distribution; plant size, siting and energy source; and integration and costing studies.

76:03A-002
MANAGING SALINE WATER FOR IRRIGATION.
Texas Tech University, International Center for Arid and Semi-Arid Land Studies,
Lubbock, Texas.
Proceedings of the International Salinity Conference, Texas Tech University,
Lubbock, Texas, August 16-20, 1976. 618 p.
(see 76:05C-002)

SECTION XIV

WATER SUPPLY AUGMENTATION AND CONSERVATION

WATER YIELD IMPROVEMENT (GROUP 03B)

76:03B-001
PLASTIC-REINFORCED ASPHALT SEEPAGE BARRIER,
Frobel, R.K., and Cluff, C.B.
Arizona Water Resources Research Center, Tucson, Arizona.
Paper Reprint, Journal of the Irrigation and Drainage Division, ASCE, Vol. 102, No. IR3, Proceedings Paper 12430, p 369-380, September 1976. 8 fig, 1 tab, 8 ref. OWRT A-059-ARIZ(3). 14-31-0001-5003.

Descriptors: Adhesion, *Asphalts, Linings, Membranes, *Plastics, *Reinforcement, *Seepage, Water resources, *Barriers, Equipment, Testing.

This report is concerned with laboratory equipment development, laboratory testing, and field investigations of a water seepage barrier consisting of plastic-reinforced asphalt. Three testing methods were utilized and evaluated in the asphalt-plastic-asphalt-chip-coated (APAC) membrane investigation. The first test method evaluated the hydrostatic puncture resistance of an asphalt-polyethylene combination. This test confirmed the hypothesis that the asphalt effectively increases the puncture resistance of the APAC membrane over that of plain polyethylene. The second test investigated the slope stability of a protective APAC chip seal. It was found that a typical 3/8-in.(9.5mm) cover aggregate remained stable on constructed slopes of 3:1 and 4:1 and also remained stable on a 2:1 slope up to a surface temperature of 122F(50C). The third test method evaluated adhesive materials and determined the best suited adhesive for sealing polyethylene overlaps. Subsequent field investigations resulted in equipment development that increased construction efficiency in the installation of the APAC membrane.

76:03B-002
EVALUATION OF A MONTHLY WATER YIELD MODEL,
Haan, C.T.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 55-60, January-February 1976. 6 fig, 3 tab, 11 ref.
(See 76:02A-003)

76:03B-003
AERIAL SPRAYING OF PHREATOPHYTES WITH ANTITRANSPIRANT,
Davenport, D.C., Martin, P.E., and Hagan, R.M.
California University, Water Science and Engineering Section, Davis, California.
Water Resources Research, Vol. 12, No. 5, p 991-996, October 1976. 6 fig, 6 tab, 7 ref.

Descriptors: *Antitranspirants, *Spraying, *Phreatophytes, *Application methods, Consumptive use, Streamflow, Groundwater, Groundwater basins, Water conservation, Water yield improvement, Transpiration, Transpiration control, Chem-control, Cottonwoods, Canopy, Foliar, Foliar application.

The use of antitranspirants for water conservation by reducing phreatophyte transpiration is discussed. Experiments were conducted to determine whether aerial spraying of a wax-based antitranspirant emulsion would provide adequate spray coverage and reduce transpiration. Multiple passes were made with (1) a fixed wing plane on salt cedar, cottonwood, and willow and (2) a helicopter on salt cedar. Spray coverage was also conducted on the ground. Scanning electron microscope photomicrographs showed considerable antitranspirant on foliage in the upper canopy and lesser amounts in the lower: the film was detected even 24 days after spraying. Aerially applied antitranspirant increased resistance to leaf water vapor diffusion by 150 percent during the first few days and by 80 percent thereafter. Results then show that (1) good coverage can be achieved by multiple passes of the aircraft and deep antitranspirant spray penetration into dense canopies is not as important as coverage of the outer foliage and (2) transpiration rates can be retarded without foliar damage. However, full assessment of the antitranspirant spraying must await more extensive field trials.

76:03B-004
CONSERVING WATER BY ANTITRANSPIRANT TREATMENT OF PHREATOPHYTES,
Davenport, D.C., Martin, P.E., Roberts, E.B., and Hagan, R.M.
California University, Water Science and Engineering Section, Davis, California.
Water Resources Research, Vol. 12, No. 5, p 985-990, October 1976. 6 fig, 9 tab, 32 ref.

Descriptors: *Antitranspirants, *Phreatophytes, *Application methods, *Water conservation, Transpiration control, Transpiration, Water yield improvement, Foliar, Foliar application, Canopy, Cottonwoods, Spraying, Hydrology, Watersheds (Basins), Stomata.

The use of antitranspirants in hydrology seeks to curtail transpiration from forested watersheds and riparian vegetation, such as salt cedar, without removing the vegetation or damaging the ecological balance. There are two main groups of antitranspirants: (1) stomatal inhibitors, which prevent the stomatal pore from opening fully, and (2) film-forming materials, which externally cover or plug stomatal pores. Basic information is provided on foliar coverage of three phreatophytes (salt cedar, willow, and cottonwood) by a wax-based film-forming antitranspirant and the effects of this coverage on transpiration, diffusive resistance, and water potential. Antitranspirants were applied by hand sprayer or backpack mist blower. Transpiration was measured by periodic weighing of potted plants and by gas hygrometer. Resistance to water vapor diffusion from the foliage was measured by a porometer and plant water potential by a pressure chamber. The results are presented. Foliar application by hand sprayer or backpack mist blower of a wax-based antitranspirant increased resistence to water vapor diffusion from phreatophyte foliage and decreased transpiration, indicating the potential of this non-destructive approach to water conservation.

SECTION XV

WATER SUPPLY AUGMENTATION AND CONSERVATION

USE OF WATER OF IMPAIRED QUALITY (GROUP 03C)

76:03C-001
SALT AND WATER BALANCE IN IMPERIAL VALLEY, CALIFORNIA,
Kaddah, M.T. and Rhodes, J.D.
Imperial Valley Conservation Research Center, Brawley, California 92227
Soil Science Society of America Journal, Vol. 40, No. 1, p 93-100, January-February 1976. 4 fig, 2 tab, 13 ref.

Descriptors: *Salinity, *Salts, Soil salinity, Water salinity, Root zone, Ground water, Surface runoff, Effluents, Water quality, California
(see 76:05B-016)

76:03C-002
SALINITY MANAGEMENT WITH DRIP IRRIGATION,
Hoffman, G.J.
United States Department of Agriculture, United States Salinity Laboratory, Riverside, California.
Drip/Trickle Irrigation, Vol. 1, No. 2, p 14-22, August 1976. 9 fig, 1 tab.

Descriptors: Salinity, Saline soil, Saline water, Irrigation, Irrigation practices, Irrigation systems.

The minimum leaching fraction for producing maximum crop yield with high-frequency irrigation is being established. Based on 2.5 years of data, the minimum leaching requirement under high-frequency irrigation is about 5% for wheat and grain sorghum, and between 10 and 15% for lettuce with 2.2-mmho/cm irrigation water. In citrus, after 2 years under drip irrigation, there were no yield or fruit quality difference between 5 and 20% leaching with 1.2-mmho/cm irrigation water, although there are significant differences in the distribution and concentration on soil salinity. Adequate irrigation management in salt-affected soils requires knowledge of and control over the soil matric potential and soil salinity. Soil matric potential can be measured with tensiometers or other soil matric potential sensors, and soil salinity can be detected with salinity sensors or the four-electrode conductivity probe. In salt-affected soils, knowledge of soil salinity in the root zone is required as feedback information to control irrigation from measures of soil matric potential. This knowledge will allow drip/trickle users to optimize the use of their systems for quality and productivity.

76:03C-003
PROCEEDINGS OF THE CONFERENCE ON SALT AND SALINITY MANAGEMENT,
California University, Davis, California 95616
Proceedings of the Conference held at Santa Barbara, California, September 23-24, 1976, Report #38, December 1976. 166 p.

Descriptors: *Salts, *Salinity, *Water management, *Water quality control, *Legislation, *Political aspects, *Institutions, Irrigation, Waste water disposal, California, Operations, Technology, Soil tolerance, Water utilization.
(see 76:05G-020)

76:03C-004
USE OF HIGHLY-SALINE WATER IN CITRUS IRRIGATION,
Goell, A., E-Rais, M., and El-Wahidi, A.
Agricultural Research Orginization, The Volcani Center, Division of Citriculture, Bet Dagan, Israel
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 236-245. 2 fig, 3 tab, 7 ref.

Descriptors: Saline, water, Salinity, Orchards, Irrigation, Irrigation effects, Chlorine, Crop response, Oranges, Soil moisture, Nutrients.

High Cl salinities in the water used to irrigate Citrus orchards in the Gaza Region on the southern coastal plain of Israel have caused yields to peak earlier, and to decline more rapidly than in orchards of the same age irrigated with water containing minimal amounts of Cl. Vegetative growth on such trees becomes less vigorous, leaves develop chlorosis, age quickly and drop earlier. Overall yields are lower and long-term profitability of the orchard is further reduced by the high incidence of 'creased' fruit. Various cultural treatments have been tried in an irrigation-frequency experiment in a Valencia orange orchard with the aim of stimulating new and more vigorous growth in the trees. A treatment combining a period of moisture stress in early summer (stoppage of irrigation) and the supply of a highly-available nitrogenous fertilizer when irrigation was resumed in mid-summer proved effective in stimulating much vigorous late summer vegetative growth. The effects of this treatment and its long-term effects on growth and cropping are discussed.

76:03C-005
SALT TOLERANCE OF BEANS UNDER A SAND MULCH CULTURE,
Parra, M.A., and Romero, G.C.
Catedra de Edafologia, Escuela Tecnica Luperior de Ingenieros Agronomos, Cordoba and Valencia, Spain.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 220-235. 5 fig, 6 tab, 20 ref.

Descriptors: Salt tolerance, Crop production, Beans, Saline soil, Salinity, Crop response.

Salt tolerance of two cultivars of beans grown for green consumption under a sand mulch culture has been studied. The influence of the growing season and the time of soil salinization on salt tolerance as well as the tolerance during germination have also been investigated. Under early salinization regimes and high evapotranspiration demands, yields were reduced by 50% of the maximum at ECse of 6 mmhos/cm. This latter figure means an almost twofold higher salt tolerance was increased by almost 100% when the crop was grown under low evapotranspiration demands (fall culture). An additional 30% salt tolerance increase was observed when soil salinization was delayed twenty days. Increasing yields of first picking and dry pod matter observed with increasing soil salinity suggest that soil salinity accelerates fruit ripening.

76:03C-006
PROBLEMS OF MANAGING GEOTHERMAL WATERS FOR IRRIGATION,
Peterson, H.B. and Shupe, J.L.
Utah State University, Department of Agricultural and Irrigation Engineering, Logan, Utah.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 211-219. 5 fig, 2 tab, 8 ref.

Descriptors: Irrigation, Irrigation water, Geothermal studies, Groundwater.

With the development of geothermal water as a source of energy, there will be considerable 'spent water' available for other purposes. In the United States most of the known geothermal basins are in the Western States where water is scarce and the need and temptation to use spent geothermal water for irrigation is great. This will also likely be true in other parts of the world. In this discussion we are concerned with minimizing or avoiding adverse effects caused by chemical constituents and not the possible benefits or damage to crops from the heat in the water

76:03C-007
SOIL SALINITY AND PLANT NUTRITIONAL STATUS,
Finck, A.
Institut f. Pflanzenemahrung u. Bodenkunde, Neue Universitat, Kiel, West Germany.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 199-210. 9 fig, 1 tab, 19 ref.

Descriptors: Saline soils, Crop production, Nutrients, Nitrogen, Calcium, Fertilization, Salinity.

Plants on saline soils not only suffer from water deficiency, but also from nutritional disturbances. Especially at low and medium degrees of salinity the surplus of some elements (nonnutrients or nutrients) or the real or induced deficiency of nutrients creates a nutritional stress that is often responsible for yield depressions. The extreme nutrient situation can partly be corrected by fertilization improving the ratio between necessary and unwanted ions in the plants as well as by improvement of other minimum factors such as trace element supply. The base of fertilization, however, should be reliable plant diagnosis considering that the usual limiting values for optimum supply or tolerance will have to be partly modified under saline conditions.

76:03C-008
CROP SALT TOLERANCE: EVALUATION OF EXISTING DATA,
Maas, E.V., and Hoffman, G.J.
United States Salinity Laboratory, Riverside, California
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 187-198. 8 fig, 1 tab, 23 ref.

Descriptors: Crop production, Salinity, Salts, Salt tolerance.

An extensive review and evaluation of the past 30 years' literature on crop salt tolerance was undertaken to assess the relative tolerance of as many agricultural crops as possible. Most crop yields decrease linearly as salt concentrations are increased above a tolerance thershold. Our best estimates of the threshold salinity and the yield decrease as a function of salinity are presented graphically for over 60 agricultural crops. The criteria required to express salt tolerance, and the factors that influence and limit the applicability of these data are discussed.

76:03C-009
PREDICTED AND ACTUAL YIELD DECLINE FROM FIFTY PERCENT INCREASE IN SALINITY OF THE COLORADO RIVER,
Robinson, F.E.
California University, Division of Agricultural Sciences, Davis, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 170-174. 1 tab, 1 ref.

Descriptors: Crop production, Sprinkler irrigation, Irrigation, Soil moisture, Salinity, Saline water, Carrots, Onions, Beans.

Six crops were grown in a sprinkler irrigated field with water applications based upon 10 cm available moisture and an application to pan evaporation ratio of 0.90. Utilizing data from the California Committee of Consultants, increase in water salinity from ECw=1.35 mmho/cm to 2 mmho/cm predicted yield decreases of greater than 10% for carrot, onions, and beans. These three crops exhibited significant field yield reductions of the same order of magnitude as that predicted. In the wheat, cabbage, and alfalfa yield predictions, the declination was less than 10% and the field yield reductions were not significant. Normal field trial yield variation tends to obscure the first 10% yield reduction due to salinity.

76:03C-010
TRANSPLANTATION OF JUNCUS SSP. ON SALINE SOILS IN EGYPT,
Zahran, M.A., El-Bagoury, I.H., Abdel Wahid, A.A., and El-Demerdasy, M.A.
Mansoura University, Department of Botony, Mansoura, Egypt.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 142-154. 2 fig, 3 tab, 11 ref.

Descriptors: Salinity, Saline soil, Crop production, Phosphorous, Nitrogen, Fertilization.

The saline lands of Egypt occupy vast areas along the Mediterranean Sea and the Red Sea coasts and in the inland deserts. Cultivation of these areas with hylophytic plants that proved to be of economic importance may extend the cultivable lands of Egypt and supply the country with raw materials for industrial purposes.

Juncus rigidus and J. acutus are salt tolerant and fiber plants. Their culms can be used as raw material in paper industry and their seeds may be used as a source of drugs and oils. Transplantation experiments in saline soil associated with Manzalla Lake of Egypt were carried out. The results were encouraging. Both species succeeded to grow but the vegetative yield of Juncus rigidus was, relatively, higher than that of J. acutus. Nitrogen-phosphorous fertilization treatments showed marked effect on the vegetative yields. The fresh and dry weights, as well as the lengths, of the culms increased progressively with the increased amount of nitrogen in soil but phosphorous fertilizer showed reverse effect. Excess phosphorous in soil hinder the uptake of nitrogen by Juncus plants.

76:03C-011
COMPOSITION OF SALINE DRAINAGE WATER IN IRAQ AND ITS USE,
Hanna, A.B.
State Organization of Soils and Land Reclamation, Baghdad, Iraq
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 590-597, 4 tab, 4 ref.

Descriptors: Drainage, Drainage water, Salinity, Salts, Dissolved solids, Calcium, Magnesium, Saline water, Water quality, Leaching.

Three years of study of the composition of drainage water indicated that the seasonal fluctuation of total salt concentration is more pronounced than the kind of salts, depending on agricultural activities and the status of water regime of the rivers. Total soluble salts in the drainage water varies from 7-32 mmhos/cm while the SAR ratio is about 5 in low saline samples and approaches 30 in other high saline water. An example is given, here, to make use of some of these saline waters in the first stages of leaching a highly saline alkali soil. This study indicated that about 20% of good quality water required for leaching was saved by using a 10 mmhos/cm drainage water having an SAR ratio of about 10 to an adjacent soil having in the top layer a conductivity of 124 mmhos/cm and an SAR of 20.

76:03C-012
SYSTEM FOR MANAGING SALINE AND RUN-OFF WATER FOR FRUIT AND CROP PRODUCTION IN ARID REGIONS OF MEXICO,
Gavande, S.A., Cluff, C.B., and Nahlawi, N.
Food and Agriculture Organization/United Nations Development Program Project, Universidad, Autonoma Agraria 'Antonio Narro', Saltillo, Coahuila, Mexico.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 575-589. 6 fig, 3 tab, 3 ref.

Descriptors: Mexico, Saline soils, Return flow, Runoff, Tailwater, Irrigation water, Saline water, Orchards, Economics, Crop production, Water quality.

Nearly 30% of the total area in Northern Mexico is extremely arid and presents some saline and alkali problems. Irrigation water from wells when available is often saline. A feasibility study by FAO for orchard development in this area showed that by using runoff water from compacted inter-row area and storing and recirculating this water, economic returns would be satisfactory. Total system of working model consisted of low cost water harvesting subsystem, simple water harvesting agri-subsystem and efficient compartmented tank system. A 20 hectare system consisting of 10 hectares of fruit and 10 hectares of dry farming were found to give internal return of 25% and benefit cost ratio of 3:1.

76:03C-013
YIELDS AND ACREAGE AS VARIABLES IN PLANNING THE USE OF SALINE IRRIGATION WATER: A CASE STUDY FROM IRAN,
Diestel, H., and Treitz, W.
Technical University Braunschweig, Leichtweiss Institute for Water Research, Braunschweig, West Germany.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 480-493. 3 tab, 26 ref.

Descriptors: Salinity, Irrigation water, Water quality, Saline water, Salts, River systems, Economics, Crop production, Leaching.

Economic aspects of the salinity of irrigation water are discussed. A case of preliminary economic planning with irrigation water quality is described. Tributaries of the Hableh Rud River contributed about 4% to the water discharge, but about 50% to the salt discharge of the river. Two schemes to divert tributary flow are evaluated from the economical (national) and financial (private) points of view. Two alternatives of use would exist with the improved river water; to apply it to the area which is irrigated without project implementation, which, in the long run, would result in yield increases, or to make use of the reduction in leaching requirement by increasing the irrigated area. It is shown that the latter alternative can be expected to be more profitable. Values are given in Rials per unit of salinity of river water which the farmers of Garmsar and the national economy could pay per year for water improvement. It is estimated that, in this case, it would be only 25% more expensive to gain land by salinity reduction than by additional supply of equal quality irrigation water.

76:03C-014
CHEMICAL RECLAMATION OF SOLONETZ-SOLOCHAKS IN THE ARARAT PLAIN AND THE POSSIBILITY OF UTILIZING SALINE WATERS FOR LEACHING AND IRRIGATION,
Petrosian, G.P.
Research Institute of Soil Science and Agrochemistry, Ministry of Agriculture of the Armenian SSR, USSR.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 466-479. 7 fig, 2 tab.

Descriptors: Sodium, Saline soils, Salinity, Sulphuric acids, Crop production, Leaching, Irrigation, Irrigation water, Irrigation practices.

Waste sulphuric acid and iron vitriol are the most efficient amendments for improving soda saline soils. Their ameliorative influence may be revealed in a very short time. Applying sulphuric acid and iron vitriol causes neutralization of alkaline reaction and desalinization of the soil, sharply increasing infiltration rate and permeability in it. On the reclamated soils high-yielding annual and perennial crops are cultivated, securing very quick returns of capital investments.

76:03C-015
POTENTIAL FOR SALINE WATER IRRIGATION OF TROPICAL SOILS,
El-Swaify, S.A., Sinanuwong, S., Daud, A.R., and Tengah, A.
Hawaii University, College of Tropical Agriculture, Department of Agronomy and Soil Science, Honolulu, Hawaii.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 358-375. 4 fig, 4 tab, 16 ref.

Descriptors: Saline water, Salts, Soil chemical properties, Soil physical properties, Irrigation, Irrigation practices, Hydraulic conductivity.

The effects of waters with defined salt concentration and ionic composition on the chemical and physical properties of irrigable tropical soils belonging to four Orders were investigated. Studies of cation exchange equilibria indicated that soil affinities for sodium ion adsorption were generally in the order of Oxisols less than Aridosols less than Mollisols less than Vertisols. As a group, however, these soils exhibited less tendency to accumulate detrimental sodium ions on the exchange complex than is known for temperate arid region soils. Evaluation of soil physical responses to changes in water quality by direct stability and hydraulic conductivity methods showed that soil susceptibilities to structural breakdown depended on the presence or absence of swelling minerals. Both were in the order of Aridisols less than or equal to Oxisols less than Mollisols less than Vertisols. It was concluded that a promising potential exists for using saline waters for irrigation of certain soils in the tropics when use of such waters is necessary for expanding available water resources.

76:03C-016

IRRIGATION WITH SALINE WATER IN SOUTH TEXAS,

Hipp, B.W.
Texas Agricultural Experiment Station, Weslaco, Texas.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 345-349. 4 fig, 6 ref.

Descriptors: Texas, Irrigation water, Saline water, Water quality, Salts, Leaching, Cotton, Saline soil.

South Texas and northeastern Mexico is highly dependent upon irrigation water with an EC that ranges from 1 to 4.4 mmhos/cm. Studies were conducted on sandy loam soil to determine the influence of irrigation water quality on salt distribution in the soil profile and to determine the importance of summer and fall rains in leaching salts from irrigated land. Cotton was irrigated with water with EC values of 1.2, 2.6, and 4.2 mmhos/cm. Soil salinity was monitored with salinity sensors after 0, 20.3, and 30.5 cm of irrigation water was applied and after 32.7 cm of rainfall. Before irrigation, EC of the 15 to 120 cm soil profile was 2.5 mmhos/cm but two irrigations (10 cm each) increased soil salinity in the 15-60 cm profile to about 2.3 and 4.5 mmhos/cm for the 1.2, 2.6, and 4.2 mmhos/cm irrigation water, respectively. Three irrigations with 4.2 mmhos/cm water resulted in soil EC of 7.2, 6 and 5 mmhos/cm at 15, 30, and 60 cm depths, respectively. Soil salinity in the root zone was decreased after 32.7 cm of rainfall in July and August. This salt application and subsequent leaching pattern is typical of the irrigated area of the South Texas and northeastern Mexico and it allows growers to use relatively saline water for irrigation.

76:03C-017

IRRIGATION WITH SALINE WATER IN THE PECOS VALLEY OF WEST TEXAS,

Moore, J., and Hefner, J.J.
Texas Agricultural Experiment Station, Pecos, Texas.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 339-344. 1 tab, 7 ref.

Descriptors: Texas, Saline water, Irrigation water, Dissolved solids, Crop production, Drainage, Irrigation effects, Irrigation efficiency, Saline soil, Salinity.

The Pecos Valley of West Texas has been under cultivation for 30 years with pump irrigated saline water averaging 2500 ppm total salts. This quantity of salts has restricted selection of crops to more salt tolerant plant species and required excessive water for leaching. Primary problems are associated with establishment of crops. Once beyond the seedling stage, growth and yield have generally been acceptable. Internal drainage remained good and severe salt buildup has not occurred because of favorable types of clay minerals and ionic composition of irrigation waters. The major problem facing the area is high production cost, especially that of pumping irrigation water. Expiration of a long term natural gas contract in 1975 led to a 500 percent increase in 1976. This has curtailed farming operations and has placed added emphasis on more efficient use of water. New concepts and modifications of present irrigation management systems are being introduced. The saline nature of the water and soils require that any changes in the overall management systems be carefully investigated to assess its future consequences on agriculture in the area.

76:03C-018

SALINITY EFFECTS ON CORN YIELD, EVAPOTRANSPIRATION, LEACHING FRACTION, AND IRRIGATION EFFICIENCY,

Stewart, J.I., Hagan, R.M., and Pruitt, W.O.
California University, Department of Land, Air and Water Resources, Water Science and Engineering Section, Davis, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 316-332. 3 fig, 4 tab, 10 ref.

Descriptors: Salinity, Crop production, Evapotranspiration, Leaching, Irrigation efficiency, Irrigation water, Saline water, Salt balance, Corn.

In each individual cropping situation there exists a 'limiting salt concentration' (LSC) at which irrigation water can no longer be absorbed by roots of plants and transpired. The LSC in any particular farm field and season depends on crop type, soil texture, and salinity of the upper profile soil solution in which germination and early root activity takes place. Irrigation water can only be concentrated to the LSC which is determined by the early conditioning of the crop, and which in future may be estimated by a preplant measurement of the upper soil salinity. Thus, a 'refusal fraction' (RF) also exists which is dependent on the LSC, and on the salinity of the irrigation water supply. The RF is the portion of applied water which remains in the soil and which contains the concentrated salts at the LSC level, when transpiration has effectively ceased. The RF pertains whether water supply is adequate for the crop or is limited, and whether or not leaching occurs. If these is leaching during the growing season in question, the RF constitutes the minimum leaching fraction which will maintain the salt balance of the root zone.

76:03C-019
IRRIGATION WITH SALINE WATER UNDER DESERT CONDITIONS,
Hardan, A.
Higher Agricultural Council, Baghdad, Iraq
Proceedings of the International Salinity Conference, Texas Tech University,
Lubbock, Texas, August 16-20, 1976, p 165-169. 2 tab, 6 ref.

Descriptors: Crop production, Groundwater, Rainfall, Salinity, Saline water, Orchards, Crop response, Salts.

A Desert Development Program was designed and initiated to determine the potentiality of agricultural production under desert conditions through the development of available groundwater and harvested rainfall. The suitability of different management practices of water, soil, and crops are under study in several stations in the Western Desert of Iraq. The central station is located about 60 km west of the town of Haditha at an elevation of 320 m above sea level. The average rainfall of this station is 11 cm. Irrigation waters of about 500, 2000, and 4000 ppm soluble salt concentration were used to irrigate pear trees, wheat, and potatoes. Data on soil salinity, tree growth, and yield of wheat and potatoes were collected and analyzed. The results show no significant difference in the growth of pear trees or in wheat production at all levels of water salinity. However, the production of potatoes decreased significantly at the 4000 ppm level of soluble salt concentration.

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN DOMESTIC AND MUNICIPAL USE (GROUP 03D)

76:03D-001
LONG-TERM EVALUATION OF SLOW-RELEASE NITROGEN SOURCES ON TURFGRASS,
Waddington, D.V., Moberg, E.L., Duich, J.M, and Watschke, T.L.
Community College of the Finger Lakes, Canandaigua, New York.
Soil Science Society of America Journal, Vol. 40, No. 4, p 593-597, July-August 1976. 5 fig, 2 tab, 3 ref.

Descriptors: *Turf grasses, *Kentucky bluegrass, *Ureas, *Nitrogen, Nutrients, Fertilization, Crop response.

Short-term studies with slow-release nitrogen sources have not provided information on the changes in response that may occur with continued use of a given material. In this study eight nitrogen sources were used to fertilize "Merion" Kentucky bluegrass for 7 consecutive years to obtain long-term results. Fertilizers used were urea, Uramite, IBDU (isobotylidene diurea), Urex(urea-paraffin matrix), ADM (plastic coated urea), Milorganite (activated sewage sludge), and two complete (NPK) fertilizers, with two-thirds of the nitrogen from ureaform or IBDU and the remainder soluble. Urea was applied every other week and the other fertilizers were applied one, two or three times per season to obtain total N of 1.46, or 2.44 kg/100 sq m. Weekly clipping yields and color ratings were used to evaluate turfgrass response to the fertilizer treatments. Milorganite, uramite, and IBDU produced more uniform growth than Urex, ADM, and the complete fertilizers. Response to Urex, ADM, and the complete fertilizer with IBDU was similar, and was often characterized by excessive growth after application. The greatest increase in response with continued use occurred with Uramite, which was the least efficient fertilizer in the first two years. At the end of the 7-year period, determinations of yield, color, and total soil N indicated that Uramite had the greatest residual effect.

SECTION XVII

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN INDUSTRIAL USE (GROUP 03E)

76:03E-001
WATER AVAILABLE FOR ENERGY--UPPER COLORADO RIVER BASIN,
Hansen, D.C.
Utah State Engineer's Office, Salt Lake City, Utah.
Journal of the Water Resources Planning and Management Division, Vol. 102, No. WR2, Proceedings of the American Society of Civil Engineers, p 341-348, November 1976. 1 tab, 5 ref.

Descriptors: *Colorado River, *Water resources, *Water rights, *Energy, Water supply.

The Upper Colorado River Basin has abundant deposits of fossil fuels and minerals, and numerous projects are in progress, planned or projected, to extract those resources. The first question that needs to be answered to make it possible for these projects to become reality is the availability of water. The Upper Colorado River Basin states are presently depleting 60% of the water apportioned to them under the Colorado River Compact of 1922. Of the 40% remaining it is difficult to specify the exact amount of water available for future development because of the uncertainty of the amount of water needed to satisfy the Indian water rights and the amount of water that has been committed to various projects by the Upper Colorado River Basin states. A joint effort between Federal, state, and Indian leaders is needed to make water available for energy development and to insure that all Indian water rights are satisfied.

SECTION XVIII

WATER SUPPLY AUGMENTATION AND CONSERVATION

CONSERVATION IN AGRICULTURE (GROUP 03F)

76:03F-001
DISTRIBUTION OF WATER AND IONS IN SOILS IRRIGATED AND FERTILIZED FROM A TRICKLE SOURCE,
Bar-Yoseph, B., and Sheikholslami, M.R.
Agricultural Research Organization, Division of Soil Chemistry and Plant Nutrition, Bet Dagan, Israel.
Soil Science Society of America Journal, Vol. 40, No. 4, p 575-582, July-August 1976. 4 fig, 12 tab, 11 ref.

Descriptors: *Irrigation practices, *Irrigation efficiency, *Irrigation systems, *Subsurface irrigation, *Application methods, Irrigation, Water distribution (Applied), Infiltration, Ion transport, Mathematical models, Moisture content, Soil types, Discharge (Water), Clays, Denitrification, Sands, Phosphates, Nitrates, Hydraulic conductivity.

Trickle irrigation is becoming increasingly important in modern agriculture, but the simultaneous distribution of water and nutrients emerging from a trickle source has been insufficiently studied. This paper reports a laboratory study of simultaneous distributions of water, NO3-N and P in clay and sandy soils irrigated daily from a trickle source. Hydraulic conductivity data, water retention curves and absorption isotherms to the soils were determined to enable verification of mathematical models against the experimental results obtained under various conditions. Adding identical amounts of water but increasing the trickle discharge rate in the sandy soil from 250 to 2,500 mililiters per hour increased the vertical movement of the wetting front and decreased horizontal movement. In a sequence of three cycles of irrigation with a nutrient solution, losses of nitrate were observed in the clay soil, probably due to denitrification processes. The restricted mobility of the phosphate ions, even in the sandy soil, implies that a preirrigation mixing of P in the soil, supplemented by its addition to the irrigation solution, is necessary to obtain a uniform P concentration in the soil volume.

76:03F-002
COMPARISON OF IRRIGATION SCHEDULES BASED ON PAN EVAPORATION AND GROWTH STAGES IN WINTER WHEAT,
Prihar, S.S., Khera, K.L., Sandhu, K.S., and Sandhu, B.S.
Punjab Agricultural University, Ludhiana, India.
Agronomy Journal, Vol. 68, No. 4, p 650-653, July-August 1976. 2 fig, 3 tab, 11 ref.

Descriptors: *Irrigation efficiency, *Irrigation effects, *Wheat, *Evaporation pans, *Growth stages, Crop response, Water conservation, Irrigation practices, Water management (Applied), Crop production, Irrigation water.

Water use efficiency improved by irrigation of winter wheat (Triticum aestivum) using a ratio of some fixed amount of irrigation water (IW) to pan evaporation. PAN-E, (cumulative evaporation from U.S. Weather Bureau class A pan less rain since previous irrigation) and scheduling according to growth stages. In a 2-year field study, IW/PAN-E ratios of 0.75 and 0.9 for scheduling irrigation to winter wheat irrespective of growth stage were compared with a combination of IW/PAN-E with growth stages and the conventional technique of irrigating at five growth stages. The 0.75 ratio irrespective of growth stage produced as large a grain yield as irrigation at five growth stages while using an average of 12 cm less irrigation. Combining IW/PAN-E with growth stages did not improve the yield. The major advantage of this approach is that the farmer need not change the amount of water from one application to the next. With rain, the interval for the next irrigation would increase.

76:03F-003
AN EXPERIMENTAL BURIED MULTISET IRRIGATION SYSTEM,
Worstell, R.V.
Agricultural Research Service, Snake River Conservation Research Center, Kimberly, Idaho.
Presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers, December 15-18, 1975, Chicago, Illinois, 15 p, 8 fig, 2 tab, 7 ref.

Descriptors: *Irrigation, *Irrigation systems, Irrigation design, Irrigation effects, Irrigation efficiency, Irrigation practices, Water conservation, Soil moisture, Soil moisture movement, Design criteria, Construction, Operations.

Criteria for the design, construction, and operation of an experimental buried lateral, gravity multiset irrigation system are presented. The system has a potential water application efficiency of 80% with very little runoff or erosion without automatic controls. With automatic controls and with water available on demand, light, frequent irrigations can be applied with efficiencies of 90 to 95%. The energy required to operate the system is minimal and labor requirements involve only periodic inspection and maintenance services. Cost and benefit estimates indicate that this system may be economically feasible, practical, and attractive at a time of rising energy costs and labor shortages.

76:03F-004
EVAPORATION REDUCTION FROM SOIL WITH WHEAT, SORGHUM, AND COTTON RESIDUES,
Unger, P.W., and Parker, J.J.
United States Department of Agriculture, Southwestern Great Plains Research Center, Bushland, Texas.
Soil Science Society of America Journal, Vol. 40, No. 6, p 938-942, November-December 1976. 5 fig, 2 tab, 20 ref.

Descriptors: *Wheat, *Grain sorghum, *Cotton, Evaporation, Soils, Soil properties, Soil water, Water conservation, Mulching.

Wheat, grain sorghum, and cotton are major irrigated crops on the Southern Great Plains. While irrigated wheat residue mulches increase soil water storage and decrease evaporation, very limited data are available regarding the effectiveness of grain sorghum and cotton (stalk) residues for this purpose. Therefore, this study was conducted to compare the effectiveness of wheat, grain sorghum, and cotton residues for decreasing evaporation under three potential evaporation conditions and to determine which residue characteristics are most effective for decreasing evaporation. The laboratory tests were conducted on Pullman clay loam soil columns at potential evaporation rates of 0.66, 0.92, and 1.29 cm/day. Besides a bare soil (check) treatment, residue treatments were 4, 8, 16, and 32 metric tons/ha for sorghum and cotton, and 8 metric tons/ha of wheat residue. Multiple regression analyses indicated that residue thickness most strongly affected cumulative evaporation and evaporation rates at selected days of the study. Other independent variables considered were potential evaporation, relative humidity, and residue specific gravity, application rate, and surface coverage.

76:03F-005
PHOSPHORUS FERTILIZATION WITH DRIP IRRIGATION,
Rauschkolb, R.S., Rolston, D.E., Miller, R.J., Carlton, A.B., and Burau, R.G.
California University, Department of Land, Air, and Water Resources, Davis, California.
Soil Science Society of America Journal, Vol. 40, No. 1, p 68-72, January-February 1976. 3 fig, 3 tab, 10 ref.

Descriptors: *Phosphorus, *Nutrients, *Fertilization, *Fertilizers, Irrigation, Irrigation system, Irrigation effects, Irrigation operation and maintenance.

Application of plant nutrients with drip irrigation systems in desirable for labor and energy savings and flexibility in timing nutrient applications. Evaluations of P movement in the soil and uptake by tomatoes were made when orthophosphate and glycerophosphate were applied through a drip irrigation system and in camparison with 26 kg of P/ha banded below the seed at planting.

A significantly higher P content was measured in seedling leaves when 26 kg of P/ha was applied by drip irrigation than when the same rate was banded. No differences in P content of whole tops of seedlings were measured at equal rates of inorganic or organic P applied through the drip system. There was a significant linear response of P uptake to P rate. With drip irrigation, orthophosphate moved a much greater distance into the soil than had been previously observed for comparable application rates per hectare. Glycerophosphate moved 5 to 10 cm farther through the soil at application rates of 6.5 and 13 kg of P/ha than did orthophosphate.

76:03F-006

AMMONIA VOLATILIZATION AND NITROGEN UTILIZATION FROM SULFUR-COATED UREAS AND CONVENTIONAL NITROGEN FERTILIZERS,
Matocha, J.E.
Texas A and M University Agricultural Research Extension Center, Corpus Christi, Texas.
Soil Science Society of America Journal, Vol. 40, No. 4, p 597-601, July-August 1976. 2 fig, 2 tab, 17 ref.

Descriptors: *Ammonia, *Nitrogen, *Ureas, Nutrients, Fertilization, Calcareous soils, Acidic soils, Cation exchange, Corn, Lime.

Ammonia volatilization was measured on acid and calcareous soils receiving sulfur-coated ureas (SCU) and highly soluble N fertilizers. Surface and mixed applications of SCU-30 (30% dissolution rate), SCU-20 (20% dissolution rate), uncoated (NH2)2CO, NH4NO3, and (NH4)2SO4 were made with and without lime to a fallowed acid fine sand. Without lime, top dressed NH4NO3, SCU-20, SCU-30, and (NH4)2SO4 lost < 1% while (NH2)2CO lost 18.5% of added N in 14 days. Topdressing lime with N caused more NH3 loss from (NH4)2SO4 than from (NH2)2CO during the initial 48 hours. However, accumulative loss for 14 days were 51.5, 22.5, 9.0, and 1.7% from (NH2)2CO, (NH4)2SO4, SCU-30 and SCU-20, respectively. Incorporating the lime with the soil prior to N addition reduced NH3 loss > 50% as compared to surface application, but mixing N with the limed acid soil did not reduce NH3-N losses. Mixing SCU with the soil appeared to increase release rate of N over topdressing, but this effect was not detected in plant response. Nitrogen uptake by corn on the acid soil substantiated some of the conclusions regarding measured NH3-N losses. Ammonia losses from N mixed with the finer textured calcareous clay loam were generally insignificant. Surface applied (NH2)2CO and (NH4)2SO4 lost significant amounts of NH3-N while losses from SCU and NH4NO3 were negligible.

76:03F-007

INFLUENCE OF LONG TERM TILLAGE, CROP ROTATION, AND SOIL TYPE COMBINATIONS ON CORN YIELD,
Van Doren, D.M. Jr., Triplett, G.B. Jr, and Henry, J.E.
Ohio Agricultural Research and Development Center, Department of Agronomy and Agricultural Engineering, Wooster, Ohio.
Soil Science Society of America Journal, Vol. 40, No. 1, p 100-105, January-February 1976. 5 tab, 12 ref.

Descriptors: *Till, Crop production, Crop response, Corn, Crops, Soybeans, Ohio, Soils.

Studies to compare the relative ability of a wide range of tillage and crop rotation combinations (3 multiplied by 3 factorial) to sustain corn production on several soils typical of Ohio were initiated in 1962. Soils were a well-drained Wooster silt loam, an imperfectly drained Crosby silt loam, a very poorly drained Hoytville silty clay loam, and a very poorly drained Toledo clay. Tillage treatments were no-tillage; plow and then plant; and plow, disk, and plant. Rotations were continuous corn, corn-soybeans, and corn-oats with each crop appearing each year in each rotation. Results are reported only for plots having equal plant density within a site-year combination, and adequate weed control. Corn yields were remarkably insensitive to tillage. The two plowed treatments had equal yield for virtually all years at each site within the same rotation.

76:03F-008
SULFUR-COATED FERTILIZERS FOR SUGARCANE: I. PLANT RESPONSE TO SULFUR-COATED UREAS,
Gascho, G.J., and Snyder, G.H.
Florida University, Department of Plant Nutrition, Belle Glade, Florida.
Soil Science Society of America Journal, Vol. 40, No. 1, p 119-122, January-February 1976. 1 fig, 2 tab, 14 ref.

Descriptors: *Fertilizer, *Fertilization, *Sugarcane, Urea, Nutrients, Crop response, Crop production, Nitrogen, Soils.

Crop growth and yield on sand soils is often limited by low N availability due to leaching losses from the soil. This study was initiated to determine if sulfur-coated urea (SCU) could supply adequate N nutrition and eliminate the need for repeated N applications for sugarcane grown on previously uncropped Immokalee fine sand in southern Florida. Single applications of two SCU's were compared with split applications of $(NH4)2SO4$(AS), each at three N rates, 56, 112, and 168 kg/ha. Application of SCU at planting in November resulted in excellent growth and high leaf N concentrations in the spring but did not provide optimum N throughout the growing season. Leaf N concentrations in late summer and tonnages of sugarcane and sugar for SCU plots approached, but did not equal, those attained with four applications of AS. Higher tonnages were recorded for the slower releasing SCU than for the faster releasing source but both SCU sources released large amounts of N before the warm summer months when N is required in the highest quantities. The data indicate that SCU's which release N more slowly and/or later application date should provide better N nutrition and eliminate the need for several split applications of soluble sources.

76:03F-009
SULFUR-COATED FERTILIZERS FOR SUGARCANE: II. RELEASE CHARACTERISTICS OF SULFUR-COATED UREA AND KCl,
Snyder, G.H., and Gascho, G.J.
Florida University, Department of Soil Chemistry, Belle Glade, Florida.
Soil Science Society of America Journal, Vol. 40, No. 1, p 122-126, January-February 1976. 4 fig, 2 tab, 11 ref.

Descriptors: *Nitrogen, *Potassium, *Fertilizers, *Fertilization, Leaching, Nutrients, Soils, Crop production, Florida.

Nitrogen release from sulfur-coated urea and K release from S-coated KCl were examined by several techniques under field conditions in three south Florida sand soils in order to assist in the interpretation of plant response data and to provide insight into the use of three slow-release fertilizer materials. Decreased thickness of S coating, higher temperatures and higher moisture generally favored nutrient release. However, considering the range of field conditions involved in the studies, variations in N and K release were comparatively small. Release was rapid during the first 6 months, averaging 70-80% of that applied, but was much slower thereafter.

76:03F-010
TIME-DEPENDENT LINEARIZED INFILTRATION: III. STRIP AND DISC SOURCES,
Warrick, A.W., and Lomen, D.O.
Arizona University, Department of Soils, Water, and Engineering, Tucson, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 5, p 639-643, September-October 1976. 3 fig, 12 ref.

Descriptors: Soil water, Soil water movement, Irrigation, Irrigation effects, Irrigation practices, Irrigation systems.

Water flow from strip and disc surface sources is analyzed using an approach similar to previous investigations with line and point sources. A line of closely spaced trickle irrigation emitters often wets a surface strip of finite width; similarly, for a single emitter the surface wetted pattern is a disc. Lines of equal matric flux potential are wider and more shallow for these sources than wetting patterns for the line and point. The moisture regime is independent of the source shape and depends only on the total flow rate for regions beyond approximately two times the strip width or disc radius.

76:03F-011
WATER USE AND PRODUCTIVITY OF WHEAT UNDER FIVE IRRIGATION TREATMENTS,
Ehlig, C.F., and LeMert, R.D.
Agricultural Research Service-United States Department of Agriculture, Western Region, Brawley, California.
Soil Science Society of America Journal, Vol. 40, No. 5, p 750-755, September-October 1976. 6 fig, 1 tab, 11 ref.

Descriptors: Irrigation Irrigation effects, Irrigation practices, Wheat, Crop production, Consumptive use, Soil moisture, Evapotranspiration, Lysimeters.

Water use and yield of wheat compared under five irrigation treatments using wheat planted in a silty clay loam soil in December and harvested in May. Water was applied at five rates from 11% more to 23% less than evapotranspiration (ET) from a weighing lysimeter planted to the same crop. Equal quantities of water per irrigation were applied at 76 mm in the pre-emergence and the first post-emergence irrigations and 102 mm in later irrigations. For a 102-mm application, an irrigation was scheduled whenever cumulative ET from the lysimeter reached 91, 102, 112, 122, and 132 mm of water, since the last scheduled irrigation for the treatments. Total amounts of 485 to 688 mm of water were applied in five to seven irrigations. Soil water content to 1.5 m decreased progressively with water applications below ET. The soil water content was determined gravimetrically before each irrigation and water use determined from differences in soil water content between irrigations plus the amount of applied water. Seasonal water use decreased progressively from 677 to 540 mm as irrigation frequency decreased, although water use in all treatments was similar for the first 120 days. Yields decreased as water applications decreased, except between the treatments equal to ET and at 10% below ET. At the three driest treatments yield decreased proportionately with water use, indicating that water use efficiency was not increased by restricting water use below ET from adequately watered wheat.

76:03F-012
NITROGEN, PHOSPHORUS, AND POTASSIUM UTILIZATION IN THE PLANT-SOIL SYSTEM: AN ANALYTICAL MODEL,
Smith, O.L.
Oak Ridge National Laboratory, Oak Ridge, Tennessee.
Soil Science Society of America Journal, Vol. 40, No. 5, p 704-714, September-October 1976. 11 fig, 2 tab, 61 ref.

Descriptors: Nitrogen, Phosphorus, Potassium, Model studies, Crop production, Crop response, Absorption, Nutrients, Simulation analysis.

An intermediate-resolution analytical model of nitrogen, phosphorus, and potassium utilization in the plant-soil system was developed and tested. Starting from specified natural or artificial sources in the soil, element transport to root absorption surfaces was modeled in terms of diffusion, mass flow, and soil buffering mechanisms. Element uptake was described by carrier theory formalism, and assimilation was based on four premises about the roles of N, P, K, and photosynthate in cell chemistry. There were three main objectives of the model. The first was to predict the first-order interactive growth response of particular plant species to any combination of these macronutrients supplied in the soil medium. Species parameters required by the model include root absorption rate and certain cell chemistry reaction rates. The second objective was to make the model sufficiently general to describe a broad range of species. It was built upon common denominator principles of physiology condensed from available experimental data on corn, bean, pine, etc. In this generic sense it is a measure of what plants have in common. The third objective was to use the model to test several well-known theories of plant growth. The model was validated against reported experiments on ryegrass, oat, a legume, and rutabaga, in which dry matter yield was measured as a function of factorial application of N, P, and K to the soil. The model shows that much of the deficient, optimal, toxic, and interacitve response of plants to N, P, and K can be explained in terms of strong linear response of cell chemistry to low nutrient concentrations and inhibition by N, P, and K at high nutrient concentrations.

76:03F-013
PHOSPHORUS-ZINC INTERACTION IN RELATION TO ABSORPTION RATES OF PHOSPHORUS, ZINC, COPPER, MANGANESE, AND IRON IN CORN,
Safaya, N.M.
North Dakota University Project Reclamation, Grand Forks, North Dakota.
Soil Science Society of America Journal, Vol. 40, No. 5, p 719-722, September-October 1976. 4 tab, 24 ref.

Descriptors: Nutrients, Fertilization, Phosphorus, Zinc, Copper, Manganese, Iron, Corn, Crop production, Crop response.

The effects of P and Zn on growth , nutrient content in tops and roots, and the rates of absorption of P, Zn, Cu, Mn, and Fe per unit fresh weight of roots for two growth periods of corn were studied in soil culture under greenhouse conditions. Visual symptoms of Zn deficiency appeared in plants when the level of applied P was raised to 75 micro g P/g soil. Phosphate decreased tissue-Zn concentration and Zn flux through roots. Zinc deficient plants had higher concentration of P in their tissues. Phosphate flux was mostly reduced with Zn, but during 27-48 days growth, Zn-supplied plants retained near identical rates of P absorption (approximately 14 micro g/g fresh root/day) irrespective of the level of P supplied. The rate of Cu absorption was reduced with both P and Zn as the plants aged. Manganese flux was initially stimulated by P but later on drastically reduced by Zn. Iron concentration in plants decreased with Zn application but significant reduction in Fe flux with Zn occurred during early growth of 25 ppm P-supplied plants only. In general, nutrient fluxes diminished with plant age.

76:03F-014
CALCIUM AND STRONTIUM ABSORPTION BY CORN ROOTS IN THE PRESENCE OF CHELATES,
Malzer, G.L., and Barber, S.A.
Minnesota University, Department of Soil Science, Minneapolis, Minnesota.
Soil Science Society of America Journal, Vol. 40, No. 5, p 727-731, September-October 1976. 3 fig, 3 tab, 13 ref.

Descriptors: *Strontium *Calcium, Corn, Crop production, Absorption, Plant growth.

While chelates have been shown to increase the flux of metal cations into roots, the mechanism has been subject to question. The objective of this research was to characterize the action of chelates on metal cation absorption. Calcium and Sr rather than micronutrient metals were used because some plant roots do not discriminate in their absorption, hence, relative flux of Ca vs. Sr could be used to evaluate uptake mechanisms. The chelates used were EDTA, DTPA, and HEDTA. Flux into corn roots was determined by monitoring Ca, Sr, and chelate depletion from solution with time. Double labeling of Ca and Sr with Ca-45 and Sr-85 was used. Ligand concentrations were measured using Cd titration, C-14-labeling, and UV-absorption measurements of Cu-ligand complexes. Calcium and Sr were removed from solution more rapidly than the chelate. Only 11 to 16% of the chelating ligand was absorbed over a 5-day period, whereas 90% or more of each of Ca and Sr was absorbed. The Ca/Sr ratio of uptake indicated that some of the Ca and Sr was absorbed directly from the chelate. However, where Ca(2+) was maintained by continual addition, chelated Ca appeared relatively unavailable to the plant.

76:03F-015
EFFECTS OF BORON AND NITROGEN ON GRAIN YIELD AND BORON AND NITROGEN CONCENTRATIONS OF BARLEY AND WHEAT,
Gupta, U.C., MacLeod, J.A., and Sterling, J.D.E.
Research Branch, Research Station, Agriculture Canada, Box 1210, Charlottetown, Prince Edward Island, Canada.
Soil Science Society of America Journal, Vol. 40, No. 5, p 723-726, September-October 1976. 5 tab, 12 ref.

Descriptors: Boron, Nitrogen, Wheat, Barley, Crop production, Crop response, Grains (crops).

In field experiments, 4.48 kq B/ha added to soil decreased the grain yield of barley and wheat. Under greenhouse conditions, 0.5 ppm, added B reduced wheat yields while 1.0 ppm added B reduced barley yields. The B toxicity in wheat in 1974 and barley and wheat in 1975 at 2.24 kg B/ha as associated with reduced yield was alleviated somewhat by the additions of N to the soil in field experiments, but the effect was not significant. Under greenhouse conditions, addition of 50 ppm N or more reduced B uptake and alleviated B toxicity. In general, the B toxicity symptoms on the foliage under field conditions were associated with > 11 ppm B in wheat boot stage tissue (BST) and > 14 ppm B in BST of barley. Added B increased the N concentration of grain where yields were decreased due to B toxicity. Wheat yields increased with increased rates of N application in all field experiments, while barley yields increased with increased rates of N in 2 of the 3 years. In field experiments the highest B value was 34 ppm. Concentrations as high as 312 ppm B were found in greenhouse experiments. In the presence of added B under greenhouse conditions, the barley tissue B concentration was much lower when the moisture level near the fertilizer band was low than when it was high.

76:03F-016
MODEL FOR PREDICTING EVAPOTRANSPIRATION FROM NATIVE RANGELANDS IN THE NORTHERN GREAT PLAINS,
Hanson, C.L.
Agricultural Research Service, Northwest Watershed Research Center, Boise, Idaho.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 471-481, May-June 1976. 5 fig, 4 tab, 42 ref.
(See 76:02D-004)

76:03F-017
PLANT WATER STRESS CRITERIA FOR IRRIGATION SCHEDULING,
Stegman, E.C., Schiele, L.H., and Bauer, A.
North Dakota State University, Department of Agricultural Engineering, Fargo, North Dakota.
Presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers, December 15-18, 1975, Chicago, Illinois, 22p, 7 fig, 6 tab, 18 ref, ASAE, Paper 75-2555.
(See 76:02G-075)

76:03F-018
UPWARD WATER MOVEMENT IN FIELD CORES,
Wells, L.G., and Skaggs, R.W.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 275-283, March-April, 1976, 12 fig, 3 tab, 29 ref.

Descriptors: *Groundwater movement, *Subsurface irrigation, *Cores, *Model studies, Laboratory tests, Theoretical analysis, Hydraulic properties, Soil properties, Soil profiles, Soil water movement, Design, Water table, Equations, Irrigation, Pressure head, Moisture content, Boundaries (Surface), Tensiometers, Hydraulic gradient, Hysteresis.

Subirrigation experiments were conducted under various initial and boundary conditions using large, undisturbed cores from two field soils. The pressure head distribution and flow volume were measured continuously, and the desorption and imbibition character of the soil water were determined using pressure plates. The effect of air entrapment on water content was determined gravimetrically, while the hydraulic conductivity-pressure head relationship was determined for each soil, from transient pressure head measurements during a drainage event. An approximate model was developed to describe vertical water movement during subirrigation. This model as well as the Richards equation were tested against experimental results from both soils. Substantial variability was evident in both measured soil properties and in water movement phenomena. The approximate subirrigation model provided acceptable agreement with the observations. Consideration of soil stratification generally improved model accuracy. For engineering design the added time and expense of sophisticated models are not justified in comparison to the approximate model. Determination of the total volume of stored water in a profile under specified boundary conditions is essential to predictions of water movement.

76:03F-019
A COMBINED MODEL FOR OPERATING IRRIGATED AGRICULTURAL SYSTEMS UNDER UNCERTAINTIES,
Amir, I., Friedman, Y., Sharon, S., and Ben-David, A.
Technion-Israel Institute of Technology, Lowdermilk Faculty of Agricultural Engineering, Haifa, Israel.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 299-304, March-April 1976. 2 fig, 5 tab, 9 ref.

Descriptors: *Irrigation systems, Agriculture, *Planning, *Operations research, *linear programming, *Simulation analysis, *Computer programs, Optimization, Decision making, Monitoring, Cotton, Q theory, Hydraulics, Scheduling, Constraints, Equations, Systems analysis, Mathematical models, *Risks.

Irrigation is a well-defined subsystem in a comprehensive agricultural production system. Both of these systems are interrelated. An adaptable ad hoc linear model has been found to be suitable for planning and operating the entire system under uncertainties. This model is the framework of the irrigation subsystem. Unfortunately, many of the factors involved in irrigation create nonlinear functions and thus cannot be directly included in the linear model. This paper suggests using a linear model to (1) solve the overall system for optimality, (2) to check by a simulation technique whether the solution is feasible and meets the irrigation system set-up and requirements, and (3) to change, if necessary, one or both of the systems in order to achieve the best feasible comprehensive solution. The combined model has been carried out for 89 possible different cotton activities of 430 ha, reflecting various irrigation equipment and methods. The outcome provides a detailed irrigation timetable and a list of the required parameters (pressure heads and discharges) for controlling the hydraulic network as well as the optimal overall solution.

76:03F-020
SURFACE RESIDUE, WATER APPLICATION, AND SOIL TEXTURE EFFECTS ON WATER ACCUMULATION,
Unger, P.W.
Agricultural Research Service, and Southwestern Great Plains Research Center, Bushland, Texas.
Soil Science Society of America Journal, Vol. 40, No. 2, p 298-300, March-April 1976. 2 fig, 14 ref.
(See 76:02G-078)

76:03F-021
VERTICAL FLOW OF AIR AND WATER WITH A FLUX BOUNDARY CONDITION,
McWhorter, D.B.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 259-265, March-April 1976. 3 fig, 1 tab, 7 ref.
(See 76:02G-082)

76:03F-022
EROSION FOR CORN TILLAGE SYSTEMS,
Siemens, J.C., and Oschwald, W.R.
Illinois University, Department of Agricultural Engineering, Urbana-Champaign, Illinois.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 69-72, January-February 1976. 3 fig, 6 tab, 14 ref.

Descriptors: *Erosion control, *Cultivation, *Farm management, Crops, Corn (Field), Rainfall, Simulated rainfall, Sediments, Nutrients, Runoff, Soil erosion, Soil conservation, Agricultural runoff, Agricultural engineering, Agriculture.

The erosion control effectiveness of six tillage-planting systems after planting in corn residue was measured. The tillage systems utilized different types and amounts of tillage in order to produce soil surfaces that varied in residue quantity and soil looseness in the tilled layer. A rainfall simulator for application of simulated rain to plots was described. Conservation tillage systems following corn such as chop-plant disk-chisel, coulter-chisel, and chisel can significantly reduce soil loss from that of fall plow. After planting, these tillage systems have a greater impact on soil loss than on surface runoff. The loss of N and P in surface runoff may not differ significantly between tillage treatments, given the fertilizer application practices followed by most Corn Belt crop producers. Conservation tillage systems can, however, significantly influence the loss of total N and P as a result of the influence on sediment removal. Total N and P loss may have little short-term influence, but accumulated losses over time will eventually influence the need for N and P fertilizers.

76:03F-023
NITROGEN FLUX INTO CORN ROOTS AS INFLUENCED BY SHOOT REQUIREMENT,
Edwards, J.H., and Barber, S.A.
Agricultural Research Service, Byron, Georgia.
Agronomy Journal, Vol. 68, No. 3, p 471-473, May-June 1976. 3 tab, 8 ref.

Descriptors: *Nitrogen, *Fertilizer, *Nutrient requirements, *Corn (Field), *Root zone, Planting management, Plant growth, Absorption.

Experiments were conducted to determine the influence of shoot N requirements on N unflux/M of corn roots. Trimmed- and split-root procedures were used for solution culture experiments in the growth chamber to vary the N absorbing roots/unit of shoot and assess the impact on N influx. Roots trimmed 2 days before influx measurement had slight increases in the N influx/m of root, causing reduced N uptake/plant. Roots split between N-containing and N-free solutions from seedling stage until influx measurement at 16 or 18 days had greater increases in net N influx than trimmed roots had. Both experiments revealed no relation between N level within the root and N uptake rate/m of root. Increased shoot demand for N does not immediately affect N influx into the root, but N stress causes an increased influx capability. Plants developing throughout their growth cycle with N restricted to part of the root system may absorb N more rapidly through those localized roots exposed to N than when N is placed into the localized portion of soil after several weeks' growth.

76:03F-024
EFFECTS OF IRRIGATION REGIMES, PLANTING DATES, NITROGEN LEVELS, AND ROW SPACING ON SAFFLOWER CULTIVARS,
Abel, G.H.
Agricultural Research Service, Phoenix, Arizona.
Agronomy Journal, Vol. 68, No. 3, p 448-451, May-June 1976. 8 tab, 7 ref.

Descriptors: *Irrigation effects, *Planting management, *Nitrogen, *Fertilization, *Crop response, Irrigation efficiency, Crop production, Arid lands, Arizona, Water management (Applied), Water conservation.

In three experiments on safflower cultivars over a 3-year period, seed yields were greater in the last two years with crops planted on December 15 than those planted February 15. Plants in two-row plots produced fewer seeds/head and smaller seeds than those in one-row plots, but increased populations in the former group compensated for such deficiencies and the yields were comparable. An irrigation regime involving early cut-off conserved water and labor, reduced weed growth, and produced optimum seed yields at lower levels of nitrogen fertilization. The best fertilization levels were from 84 to 336 kg/ha, according to the planting date, irrigation regime, and cultivar. For the Laveen clay loam soil at the test site (Mesa, Arizona), 168 kg/ha was optimum for a December planting; quantities exceeding 84 kg/ha had no yield advantage with a February planting. The "Dart" cultuvar outyielded all others used, especially when given the optimum fertilization and irrigation treatment.

76:03F-025
SOIL WATER UPTAKE BY ALFALFA,
Khol, R.A., and Kolar, J.J.
Agricultural Research Service, Kimberly, Idaho, Snake River Conservation

Research Center.
Agronomy Journal, Vol. 68, No. 3, p 536-538, May-June 1976. 4 fig, 14 ref.

Descriptors: *Soil water movement, Soil water, *Moisture uptake, *Alfalfa, *Soil-water-plant relationships, Root zone, Xylem, Soil profiles, Moisture stress.

Soil water uptake by alfalfa was studied by monitoring a seed crop with a neutron moisture probe. Plant water potential measurements support passive uptake. Water was withdrawn in the lower root zone, where soil matric potentials were between -7 and -10 bars, while the upper portion of the profile was above -2 bars. Results indicate that passive water uptake requires large water potential differences between the root xylem and soil in the moist upper portion of the profile. Alfalfa plant moisture potentials decreased through the growing season, possibly due to moisture stress and maturity. While water is preferentially taken up from layers where the soil water potential is high, it continues being withdrawn from layers of lower potential. Root location (shallow or deep) does not appear to influence water uptake.

76:03F-026

CORN PLANT WATER STRESS AS INFLUENCED BY CHISELING, IRRIGATION, AND WATER TABLE DEPTH,

Reicosky, D.C., Campbell, R.B., and Doty, C.W.
Agricultural Research Service, Coastal Plains Soil and Water Conservation Research Center, Florence, South Carolina.
Agronomy Journal, Vol. 68, No. 3, p 499-503, May-June 1976. 5 fig, 3 tab, 7 ref.

Descriptors: *Corn (Field), *Water table, *Soil-water-plant relationships, Crop production, Soil management, Crop response, *Irrigation effects, Stomata, Cultivation, Moisture stress, *Chiseling.

Chiseling and irrigation effects on plant water status were evaluated through leaf water potential, stem diameter and stomatal resistance measurements. Corn grown on a Varina sandy loam chiseled to 38 cm was compared with that grown on conventionally tilled plots. Chiseling had no effect on daily minimum leaf water potential the first year (1972) and only a slight effect on stomatal resistance, but irrigating had some beneficial effect. At tasseling in 1973, with a water table 80 cm from the surface, chiseling produced deeper-rooted corn that allowed water utilization in the capillary fringe above the water table; leaf water potential increased slightly while stomatal resistance and stem diameter fluctuation decreased. Plant-water status on chiseled plots was similar to that on furrow-irrigated plots. Improved midday plant water status caused an 8-metric ton/ha increase in corn ear yields. Results indicate that chiseling of soils with root restricting layers can increase corn production, especially when the water table is about 80 cm from the surface tasseling.

76:03F-027

FERTILIZATION, NUTRIENT COMPOSITION, AND YIELD RELATIONSHIPS IN IRRIGATED SPRING WHEAT,

Gardner, B.R., and Jackson, E.B.
Arizona Agricultural Experiment Station, Department of Soils, Water, Engineering and Plant Sciences.
Agronomy Journal, Vol. 68, No. 1, p 75-78, January-February 1976. 3 fig, 5 tab, 5 ref.

Descriptors: *Nitrates, *Fertilization, *Crop response, *Nutrient requirements, *Wheat, Arizona, Root zone, Crop production, Testing procedures, Plant tissues, Phosphates.

The effect of N fertilization on the growth and yield of semidwarf spring wheat in the Yuma Valley of southwestern Arizona and a tissue test as guide for applying such fertilizers is presented. Excessive N used is evaluated, in two field experiments reduced yields slightly when compared with sufficient N levels. Application of 336 kg N/ha produced the best yields, with no further increase resulting from higher rates. Yields intermediate between control and high-yield results were achieved with 112 and 224 kg/ha rates prior to planting;

similar results at those two rates suggest much of the N applied preplant was leached from the root zone. N caused increases in number of heads/unit area and seeds/head, with a decrease in the weight of individual seeds. Total N content in the grain increased with larger N applications. Determination of P in the lower portion of wheat stems was of doubtful value in determining the crop's P status.

76:03F-028
IRRIGATION SYSTEMS IN TAIWAN: MANAGEMENT OF A DECENTRALIZED PUBLIC ENTERPRISE,
Abel, M.E.
Minnesota University, Department of Agricultural and Applied Economics, Saint Paul, Minnesota.
Water Resources Research, Vol. 12, No. 3, p 341-348, June 1976. 1 fig, 1 tab, 22 ref.

Descriptors: *Irrigation systems, *Canals, *Management, *Irrigation efficiency, Water resources, Planning, Operations, Agriculture, Water policy, Engineering, Agronomy, Legal aspects, Administration, Rice, Water utilization.

The efficiency of the management of irrigation systems in Taiwan, viewed as decentralized public enterprises, depends on four interrelated factors: (1) the recognition that water is a scarce factor in agricultural production; (2) the legal administrative basis for centralized planning of irrigation investments but decentralized management of irrigation systems; (3) the information systems which permit the exchange of agronomic and engineering information between the users of water and the managers of irrigation systems; and (4) the use of incentive structures for both the managers of irrigation systems and the users of water that appear to be compatible with the efficient use of water within the irrigation system. Discussed also is the true complexity of irrigation systems and irrigated crop production found in Taiwan today with which the management of these systems must contend.

76:03F-029
WEATHER-DEPENDENT PRICING FOR WATER RESOURCES IN THE TEXAS HIGH PLAINS,
Lane, M.N., and Littlechild, S.C.
International Bank for Reconstruction and Development, Washington, D.C.
Water Resources Research, Vol. 12, No. 4, p 599-605, August 1976. 4 tab, 9 ref.

Descriptors: *Irrigation water, *Pricing, *Linear programming, Optimization, Weather, Reservoirs, Water supply, Farms, Profit, Crops, Constraints, Costs, Rainfall, Equations, Mathematical models, Systems analysis.

Two alternative schemes for pricing irrigation water are examined. Under the first scheme, price is independent of weather; in the second scheme, price varies with weather so as to generate just enough demand to exhaust reservoir capacity. The second scheme provides savings through the more efficient utilization of available reservoir supplies and through the curtailing of demand so as to allow the construction of smaller reservoirs. The analysis proceeds by means of a linear programming under uncertainty model of a representative farm. The model is applied to the High Plains of Texas. Results suggest that the weather-dependent pricing scheme would increase farm profits by the order of 10% per annum.

76:03F-030
OPTIMIZATION OF CROP IRRIGATION STRATEGY UNDER A STOCHASTIC WEATHER REGIME: A SIMULATION STUDY,
Ahmed, J., van Bavel, C.H.M., and Hiler, E.A.
Water Resources Research, Vol. 12, No. 6, p 1241-1247, December 1976. 5 fig, 2 tab, 26 ref.

Descriptors: *Irrigation efficiency, *Crop response, *Water utilization, *Simulation analysis, *Optimization, Crops, Decision making, Weather, Texas, Sorghum, Soil, Atmosphere, Water resources, Management, Agriculture, Computer models, Equations, Operations research, Irrigation water, Water policy, Conservation.

A dynamic simulation model of the soil-water-atmosphere-plant system is developed as a tool for irrigation decision making under a stochastic weather regime and when water supplies are limited. Crop yield, foliage development, plant water deficits, and irrigation decisions have been treated as interdependent processes. Yield susceptibility of the crop to water deficit is a function of crop growth stage. The stomatal regulation of transpiration by the crop has been accounted for as well. The model is a closed loop dynamic system, in which past irrigation decisions and weather conditions affect the current as well as the future response of the crop system, and consequently, the future irrigation decisions and the overall water use efficiency. Determined are the optimal irrigation timing and quantities; estimated are the associated yields, the water use efficiencies, and the trade-offs between water conservation and crop yield. The crop growth and yield simulation consists of two parts: (1) a dynamic crop growth and plant behavior model under stochastic weather regime and specific irrigation strategy; and (2) a seasonal crop stress computation for the simulated crop with associated yield estimates. The optimization criteria, water use efficiency, is defined as the ratio of crop yield to total amount of irrigation water used in its production. Specific illustration is given by considering grain sorghum grown under weather conditions typical for south central Texas.

76:03F-031
POTASSIUM SOURCES AND AVAILABILITY ON A DEEP, SANDY SOIL OF EAST TEXAS,
Hons, F.M., Dixon, J.B., and Matocha, J.E.
Texas A and M University, Department of Soil Mineralogy, College Station, Texas.
Soil Science Society of America Journal, Vol. 40, No. 3, p 370-373, May-June 1976. 2 fig, 4 tab, 28 ref.

Descriptors: *Potassium, Nutrients, Soil properties, Bermuda grass, Soil investigations, Soil profiles, Fertilization, Root development.

Soil properties were assessed that may have contributed to the failure of Coastal bermudagrass to respond to application of K on Darco fine sand for 5 consecutive years. The depth to which plant roots absorbed K was assessed by field observation and by determination of K levels in control and treatment plots. Potassium minerals were determined by chemical methods to assess potential nutrient sources. Potassium removal was indicated to at least 160 cm by soil solution content and to 235 cm by exchangeable K concentration and Gapon selectivity values. Depth of bermudagrass rooting was in agreement with chemical indicators of K removal.

76:03F-032
GASEOUS LOSS OF AMMONIA FROM SULFUR-COATED UREA, AMMONIUM SULFATE, AND UREA APPLIED TO CALCAREOUS SOIL (PH 7.3),
Prasad, M.
M.J. Woods and Associates, 13 Kilbarrack Grove, Dublin, 5, Ireland.
Soil Science Society of America Journal, Vol. 40, No. 1, p 130-134, January-February 1976. 7 tab, 20 ref.

Descriptors: Urea, Nitrogen, Temperature, Calcareous soil, Soil moisture, Ammonia, Nutrients.

Laboratory incubation experiments were conducted to study the comparative volatilization loss of NH3 in a calcareous soil from sulfur-coated urea (SCU) with fast (F), medium (M), and slow (S) dissolution rates, ammonium sulfate (AS) and urea, at two temperatures 22 and 32C, and at three soil moisture levels 25, 50, and 80% of the water holding capacity of the soil. The effect of the addition of organic amendment (filter press mud) to soil on NH3 loss from these N-sources was also studied. Loss were studied up to 21 days. At both temperatures increasing soil moisture levels led to reduction of NH3 loss regardless of the N-source, despite the fact that the soil analysis showed higher dissolution of N from SCU at high soil moisture.

76:03F-033

HIGH-FREQUENCY IRRIGATION FOR WATER NUTRIENT MANAGEMENT IN HUMID REGIONS,

Phene, C.J., and Beale, O.W.
United States Department of Agriculture, Coastal Plains Soil and Water Conservation Research Center, Southern Region, Florence, South Carolina.
Soil Science Society of America Journal, Vol. 40, No. 3, p 430-436, May-June 1976. 8 fig, 2 tab, 16 ref.

Descriptors: Subsurface irrigation, Irrigation systems, Irrigation, Irrigation effects, Nutrients, Humid climates, Humid areas, Soil water, Fertilization, Crop response, Corn, Furrow irrigation, Sprinkler irrigation, Leaching.

A water-nutrient management method was designed to prevent plant-water and nutrient stresses while maximizing the available soil water storage to accomodate rainfall. This method minimized the need for the soil as a storage reservoir for water and nutrients by frequently irrigating a portion of the root zone with small amounts of water and nutrients. The optimal range of soil matric potential, based on soil oxygen diffusion rate, soil strength, water desorption characteristics, and unsaturated hydraulic conductivity was used to determine high-frequency irrigation criteria for sweet corn. Trickle-irrigated plots yielded 12 and 14% more corn than did the furrow-and sprinkler-irrigated plots. When fertilizers were broadcast and banded, soil NO3-N profiles measured near the end of the growing season showd that, compared to furrow and sprinkler irrigation, trickle irrigation reduced NO3-N losses from the root zone.

76:03F-034

THE EFFECTIVENESS OF A MIST VERSUS A LOW PRESSURE SPRINKLER SYSTEM FOR BLOOM DELAY,

Wolfe, J.W., Lombard, P.B., and Tabor, M.
Oregon State University, Southern Oregon Experiment Station, Department of Agricultural Engineering, Corvallis, Oregon.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 510-513, Special Edition 1976. 4 fig, 2 tab, 7 ref.

Descriptors: *Orchards, Oregon, Sprinkler irrigation, Sprinkling, Irrigation effects, Irrigation practices, Irrigation.

This paper deals primarily with tests made on a fogging or misting system installed for bloom delay in a pear orchard at Medford, in comparison with a system using small sprinklers. Conclusions include: 1. A misting system provided greater cooling for bloom delay than a low-pressure sprinkler system when the water application rate was about 3 l/s ha (19 gpm per acre). 2. A bloom delay of 11 days was observed in Bartlett trees and 9 days in Bosc under the mist system tested during a late season. To obtain more delay during an early season would likely require running the system more hours. 3. The mist system required only about 60 percent as much water per day of delay as the sprinklers did. 4. A mist-system capacity of 3 l/s ha provided almost as many degrees of cooling on a day when the maximum air temperature was 10.6C (51F) as on a much warmer day, suggesting that the cooling efficiency for this system had nearly reached its maximum at 10.6C (51F). 5. The mist system is easier to install on established hedgerows than on large trees and appears to function at least as well as many permanent overhead sprinkler systems used for frost control by encasing the trees in ice. 7. More research is needed to develop criteria for an economical system design for mist including determining the minimum required system capacity, the optimum (minimum) pressure required for adequate breakup of drops, a satisfactory filtration system, and the least elaborate layout for placing the mist uniformly on the trees.

76:03F-035

AN EVALUATION OF SULFUR-COATED UREA AS A PREPLANT TOTAL SEASON NITROGEN SUPPLY FOR TRELLISED TOMATOES,

Shelton, J.E.
North Carolina State University, Department of Soil Science, Raleigh, North Carolina.
Soil Science Society of America Journal, Vol. 40, No. 1, p 126-129, January-

February 1976. 2 fig, 2 tab, 5 ref.

Descriptors: *Urea, Nitrogen, Nutrients, Fertilization, Tomatoes, Crop response, Sampling, Crop production.

The use of a controlled release N source for the production of trellised tomatoes which require frequent topdressings would be desirable. Three sulfur-coated urea (SCU) materials having release rates of 11.4, 21.5, and 29.3% over a 7-day period were compared to NH4NO3 applied preplant or as multiple applications. Nitrogen rates were 392,560 , and 729 kg N/ha. Marketable yields from an application of SCU(11.4) at 392 or 560 kg N/ha were greater than with the same rate of N as NH4NO3 either as preplant or split applications. When SCU(21.5) or SCU(29.3) was used, the yields were comparable to a single application of NH4NO3. Differences in fruit number per plot were not significantly related to treatments. However, there was a significant difference in average fruit weight which was correlated with total yield. Tissue N content was highest at the first sampling from a single application of NH4NO3 and lowest from SCU(11.4). However, at later sampling periods the N content was maintained at a higher level with SCU(11.4). Although 729 kg N/ha as a single application of NH4NO3 detrimentally affected plant growth and production, this effect was not noted with the sulfur-coated materials.

76:03F-036
INFLUENCE OF ROW SPACING AND STRAW MULCH ON FIRST STAGE DRYING,
Adams, J.E., Arkin, G.F., and Ritchie, J.T.
Agricultural Research Service, United States Department of Agriculture, Southern Region, Temple, Texas.
Soil Science Society of America Journal, Vol. 40, No. 3, p 436-442, May-June 1976. 10 fig, 2 tab, 14 ref.

Descriptors: Evaporation, Grain sorghum, Drying, Plant populations, Mulching, Crop production, Crop response.

Evaporation during first stage drying was measured with evaporation plates on the soil surface in grain sorghum plots with 25-, 50-, and 100-cm row spacings, during several stages of grain sorghum development in 1972 and 1973. Evaporation during first stage drying was affected by row spacing, leaf area index (LAI), and soil shading. Both LAI and soil shading were related to row spacing and plant population. The more complete plant canopy of grain sorghum with narrow-row spacing decreased penetration of radiant energy to the soil surface and reduced the evaporation rate of soil water during first stage drying. Evaporation was greatest during the early part of the season when shading was least and lowest during boot stage and pollination, when all leaves were fully expanded and provided maximum plant canopy and soil shading. Narrow-row spacing established an earlier, and more complete plant canopy than conventional 100-cm row spacing and shaded more of the soil surface from early vegetative growth to maturity. Soil surafce shaded near solar noon was a better indicator of first stage evaporation beneath a canopy than LAI. The combined effect of a mulched surface and a plant canopy on reducing evaporation was the product of the fractional reduction in potential mulched surface with no canopy cover. An empirical equation was developed from the evaporation data for use in calculating first stage evaporation as related to potential evaporation, fraction of the soil surface shaded, and mulch rate.

76:03F-037
DEEP PERCOLATION IN A FURROW-IRRIGATED SANDY SOIL,
Linderman, C.L., Mielke, L.N., and Schuman, G.E.
Agricultural Research Service, United States Department of Agriculture, Department of Agricultural Engineering, Nebraska University, Lincoln, Nebraska.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 250-253, Special Edition 1976. 6 fig, 1 tab, 20 ref.

Descriptors: *Deep percolation, *Furrow irrigation, Sands, Irrigation, Irrigation effects, Fertilization.

Irrigating sandy soils with shallow water tables creates a potential for deep percolation losses of water and nitrogen and consequently, nitrate pollution of groundwater. The amount and nitrate content of percolate was measured with eight vacuum extractors buried below the root zone in a sandy, furrow-irrigated cornfield. Total irrigation-season percolation was 17.6 cm, which was 25 percent of the water leaving the root zone. The maximum percolation rate was over 0.37 cm/day when the corn root system was not yet fully developed and when heavy rainfall followed irrigating. More frequent irrigations with smaller amounts of water should reduce percolation. Percolation of nitrate-nitrogen was 2.5 kg/ha/cm of percolate when N (67 kg/ha) was applied in solution in the irrigation water and 3.0 kg/ha/cm of percolate when anhydrous ammonia N (90 kg/ha) was sidedressed. Percolation of nitrate-nitrogen was affected more by total deep percolation of water than by the method of fertilizer application.

76:03F-038
A WATER SPRINKLER FOR ARBITRARILY SHAPED AREAS,
Burgdorf, O., and Henderson, J.M.
Westinghouse Electric Corporation, Sunnyvale, California.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 704-707, Special Edition 1976. 9 fig, 2 tab, 2 ref.

Descriptors: Sprinkling, Sprinkler irrigation, Irrigation, Irrigation systems, Irrigation practices, Winds, Uniformity coefficient.

The concept of watering arbitrary areas from a single moving nozzle shows reasonable promise. The average 28 percent distribution error reflects an acceptable trade-off required to gain a 13.72 m (45 ft) range capability with 0.172 MPa (25 psi) water pressure. This project has given visibility to factors important to the continuation of design of sprinklers for watering arbitrarily shaped areas: 1. trade-off considerations between coherent flow (low range, harsh water impact and high uniformity); 2. kinematic limitations inherent in simple devices which depend solely on water pressure for system motion and control; 3. wind influence; 4. mechanisms for perimeter specification; and 5. optimization techniques which allow synthesis of control mechanisms for best available distributions. The concept offers potential for certain agricultural applications. For example, adjacent square patterns could prove more cost effective than overlapping rotational systems. It is necessary to seek alternate designs which keep the nozzle (or nozzles) at relatively low elevation angles to minimize wind effects.

76:03F-039
EFFECTIVE PRECIPITATION OF VARIOUS APPLICATION DEPTHS,
Heermann, D.F., and Shull, H.H.
Agricultural Research Service, United States Department of Agriculture, Department of Agricultural Engineering, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 708-712, Special Edition 1976. 8 fig, 3 tab, 21 ref.

Descriptors: Lysimeters, Rainfall, Rain, Evapotranspiration, Water requirements, Crop production.

Irrigators have always questioned how effective small rains and light irrigations are in meeting crop water requirements. Data from precision weighing lysimeters indicated that very small rains offset the normal water use by the plants and, therefore, very effectively meet crop water requirements.

76:03F-040
CALCULATING EVAPORATION FROM NATIVE GRASSLAND WATERSHEDS,
Ritchie, J.T., Rhoades, E.D., and Richardson, C.W.
United Stated Department of Agriculture, Agricultural Research Service, Department of Soil Science, Temple, Texas.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1098-1103, Special Edition 1976. 5 fig, 1 tab, 17 ref.

Descriptors: *Evapotranspiration, Evaporation, Grassland, Computer model, Model studies, Transpiration, Soil water, Soil moisture.

Evaporation from soil and plant surfaces in many natural grassland sites will often be less than potential evaporation because of sparse vegetation or soil water deficits in the root zone. A computer model developed for calculating daily evaporation from row crop surfaces with partial cover was modified for use on native grasslands. Daily evaporation is computed by adding independently calculated soil evaporation and transpiration. Potential evaporation is calculated from commonly available atmospheric information. Soil evaporation rate is related to soil hydraulic properties, mulch cover, and potential evaporation rate. Transpiration rate is related to potential evaporation through the green leaf area index and the soil water status of the root zone. Daily evaporation was calculated for three small native grassland watersheds where runoff, rainfall, and soil water content were measured. Seasonal changes in soil water content were calculated based on drainage rates computed from the amount of infiltration in excess of the upper limit of extractable soil water and calculated evaporation rates. Calculated changes were usually within ± 5 cm of measured soil water during a 1-year period.

76:03F-041

MULCH, NITROGEN, AND IRRIGATION EFFECTS ON GROWTH, YIELD, AND NUTRIENT UPTAKE OF FORAGE CORN,
Khera, K.L., Khera, R., Prihar, S.S., Sandhu, B.S., and Sandhu, K.S.
Punjab Agricultural University, Department of Soils, Ludhiana, India.
Agronomy Journal, Vol. 68, No. 6, p 937-941, November-December 1976. 5 fig, 6 tab, 17 ref.

Descriptors: Mulching, Nitrogen, Irrigation effects, Crop response, Nutrients, Temperature, Soil temperature, Crop production, Corn.

Nitrogen, irrigation, and soil-temperature regime are major factors influencing crop growth. Hot season crops in tropical areas are reported to benefit from soil temperature reductions caused by straw mulching. But how the mulch would affect the nitrogen and irrigation requirements of the crop is not known. The independent and combined effects of two rates of straw mulch, viz., 0 and 6 metric tone/ha; three rates of nitrogen, viz., 50, 100, and 150 kg N/ha; and three levels of irrigation, viz., 7.5 cm irrigations based on irrigation water (IW)/pan-evaporation (PAN-E) ratios of 0.6, 0.9, and 1.2 on forage corn in a 2-year field experiment were studied. Green and dry forage yields and uptake of N and P significantly increased with mulching and with each successive increment of nitrogen. As the IW/PE ratio increased from 0.6 to 0.9, the green and dry forage yields and nutrient uptake increased significantly, but declined with further increase in irrigation. As a 2-year average, mulching increased the dry forage yield by 11.8 quintals/ha or 26 percent and showed a significant interaction with nitrogen rates. Fifty kg and 100 kg N/ha with mulch yielded as much as 100 kg and 150 kg N/ha without mulch, respectively. It is indicated that straw mulching in forage corn during hot and dry season increases yield and nutrient uptake and helps economize nitrogen.

76:03F-042

GROWTH RATE AND NUTRIENT UPTAKE OF TWO COTTON CULTIVARS GROWN UNDER IRRIGATION,
Halevy, J.
The Volcani Center, Agricultural Research Organization, Bet Daga, Israel.
Agronomy Journal, Vol. 68, No. 5, p 701-705, September-October 1976. 2 fig, 3 tab, 22 ref.

Descriptors: *Cotton, Irrigation, Irrigation practices, Crop response, Nutrients, Nitrogen, Phosphorus, Potassium, Semi arid climates.

The production of high cotton yield is highly dependent on adequate growth rate and nutrient uptake about which relatively little information is available under semiarid conditions. Growth rate and N, P, K uptake of two cotton cultivars, "Acla 1517-C" and "Acala 4-42," which differ in their response to K fertilizer, were investigated in an irrigated field under favorable conditions conducive to high yields. The rate of dry matter production was slow unitl flowering and after the first bolls opened. Up to 72 days from emergence, 15 percent of the total dry matter was produced; from 112 days until picking, 10 percent; and during the 40-day period to 72 to 112 days, 75 percent. Throughout this period the growth rate was nearly linear, 250 kg/ha/day. Total dry matter was 12,200 to 13,480 kg/ha. Its distribution in mature plants was 26 percent in the leaves, 24 percent in stems, 16 percent in burs, 21 percent in seeds, and 13 percent in lint. The lint yield was 1,700 kg/ha. Total uptake of N, P, and K was 230, 45, and 174 kg/ha. The total uptake of N and P followed that of dry matter production, whereas K was absorbed more rapidly, reaching a maximum at 112 days from emergence and then decreasing. The removal of nutrients from the field by seed and lint was 98 to 109 kg N/ha, 19 to 21 kg P/ha, and 43 to 47 kg K/ha.

76:03F-043
REDUCING TAILWATER RUNOFF FOR EFFICIENT IRRIGATION WATER USE,
Schneider, A.D., New, L.L., and Musick, J.T.
United States Department of Agriculture, Southwestern Great Plains Research Center, Department of Agricultural Engineering, Bushland, Texas.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1093-1097, Special Edition 1976. 4 fig, 3 tab, 8 ref.

Descriptors: *Tailwater return flow, Irrigation, Irrigation practices, Furrow irrigation, Surface irrigation, Grain sorghum, Crop production, Crop response.

Tailwater runoff from 570-m graded furrows was varied from 0 to 8 hr to determine the variability of grain sorghum yield with length of run. During the first 3 to 4 hours, cumulative infiltration into the Pullman clay loam is 5 to 7 cm. Infiltration into the slowly permeable soil then approaches the steady-state rate of less than 0.25 cm/hr. Continuing to irrigate after the entire furrow reached the steady-state infiltration rate did not significantly increase the field average yield. The root zone at the tail end of the field was not fully wetted, but the soil water was sufficient for normal plant growth, and tailwater runoff was less than 10 percent of the applied water. As a result, the irrigation water-use efficiency varied inversely as the duration of tailwater runoff. By reducing the duration of tailwater runoff, additional land could be irrigated with the limited groundwater supply.

76:03F-044
AN ASPHALT INCORPORATOR AND PACKER FOR LINING IRRIGATION DITCHES,
McLaughlin, N.B., Dyck, F.B., and Sommerfeldt, T.G.
Agriculture Canada, Research Station, Research Branch, Swift Current, Saskatchewan, Canada.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1085-1088, Special Edition 1976. 7 fig, 1 ref.

Descriptors: *Channel improvement, *Asphalt, *Linings, Irrigation, Irrigation systems, Ditches.

In laboratory experiments, an asphalt emulsion mixed with soil has shown promise of being a suitable lining material for irrigation ditches. Prototype machinery developed for lining a field lateral with the mixture in order that it may be evaluated under field conditions is duscussed. The incorporator is a large rototiller with a double-cone rotor whose longitudinal section conforms to the ditch cross section. The rototilling action mixes asphalt with the upper 8 cm of soil in the ditch profile. The packer is a large double-con roller with a longitudinal section that also conforms to the ditch cross section. Operation of the two machines in the field is discussed.

76:03F-045
AGRICULTURAL DRAINAGE WATER AS A BASIS FOR WILDLIFE DEVELOPMENT IN THE SAN JOAQUIN VALLEY OF CALIFORNIA,
Dickey, G.L., Rivera, R.A., Hewes, B.J., and Sussman, M.W.
United States Department of Agriculture, Soil Conservation Service, Department of Civil Engineering, Davis, California.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 862-865, Special Edition 1976. 3 fig, 3 tab, 15 ref.

Descriptors: *Drainage, *Drainage water, *Marshes, Drainage effects, California, Return flow, Wildlife habitat, Wildlife management.

Important marshland habitat in California is estimated at 1.94 million ha (4.8 million acres) with State and Federal ownership totaling about 93,555 ha (231,000 acres). Some of the habitat area has a partial water supply, some a full supply, but much of it has very little water. Agricultural drainage could provide a full water supply for up to 127,170 ha (314,000 acres) of wildlife habitat by the year 2000. The impact of such usage would be greatly beneficial both to wildlife habitat development and to irrigated cropland. Agricultural drainage can provide a firm water supply for wildlife and the wildlife use will allow the development of on-farm drainage systems to maintain land productivity. Further, such a short-term plan would be easily adaptable and in fact complementary to a long term plan for a master drainage system to be implemented at a later date.

76:03F-046
EFFECT OF P, CA, AND MG CONCENTRATIONS IN SOLUTION CULTURE ON GROWTH AND UPTAKE OF THESE IONS BY RICE,
Fageria, N.K.
National Research Center for Rice and Beans, Caiza Postal 179, Goiania-Goias, Brazil.
Agronomy Journal, Vol. 68, No. 5, p 726-732, September-October 1976. 5 fig, 3 tab, 28 ref.

Descriptors: Fertilization, Fertilizer, Nutrients, Phosphorus, Calcium, Magnesium, Rice, Crop response, Crop production.

Nutrient requirements during various phases of plant growth are affected by many factors. Greater knowledge of this subject is warranted by the intensification of agriculture. The present study was undertaken to determine the effect of varying concentrations of P, Ca, and Mg on the growth and uptake patterns of these ions by rice. Rice plants were grown in culture solution of these ions. Minimum concentrations required for maximum growth were 25 microM P, 250 microM Ca, and 33 microM Mg, respectively. At higher P concentrations a linear absorption isotherm was obtained with respect to P content in the plant tissue. The critical concentration of P in the tops of 100-day old plants was 0.4 percent. To support maximum growth, Ca content varied from 242 to 2,373 micro g-atoms/five plants for 25 to 125 days of growth. Maximum growth was characterized by a relative absorption (I(M)) rate ranging from 14 to 320 micro g-atoms of Ca/g dry weight of roots/day during the period of cultivation. To support maximum growth, plants must absorb 13.7, 7.7, 4.3, 4.0, and 2.4 micro g of magnesium per g fresh weight of roots/hour at 25, 50, 75, and 100, and 125 days of growth, respectively. With the advancement of age, P and Ca content in plants and their utilization quotients were increased but relative growth rate and rate of Ca and Mg absorption decreased.

76:03F-047
IRRIGATION CONTROL USING TENSIOMETERS AND SALINITY SENSORS,
Oster, J.D., Willardson, L.S., van Schilfgaarde, J., and Goertzen, J.O.
Agricultural Research Service, United States Department of Agriculture, Department of Soil Science, Riverside, California.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 294-298, Special Edition 1976. 5 fig, 1 tab, 24 ref.

Descriptors: Irrigation practices, Irrigation, Leaching, Tensiometers, Lysimeters, Evapotranspiration, Root systems.

Pressurized, high-frequency irrigation systems can be controlled to provide a nearly constant prescribed leaching fraction by use of salt sensors and tensiometers in combination as a dual feedback system. A lysimeter experiment evaluated the optimum depth of sensor placement and provided experience for the appropriate selection of control settings, both of which are strongly dependent on root water uptake distribution.

76:03F-048
TRAVELING GUN APPLICATION UNIFORMITY IN HIGH WINDS,
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Transactions of the American Society of Agricultural Engineers, Soil and Water, p 254-258, Special Edition, 1976. 5 tab, 7 ref.

Descriptors: *Uniformity coefficient, *Sprinkle irrigation, Irrigation systems, Irrigation practices, Winds, Wind velocity.

Field tests of a traveling gun sprinkler irrigation system showed that increases in wind vleocity must be accompanied by decreases in travel lane spacing if an acceptable water application uniformity is to be maintained. Travel lane spacing must be decreased further as the wind direction and travel direction become more nearly parallel. An empirical equation is presented to estimate lane spacing as a function of wind velocity and direction, and sprinkler water pressure, for the sprinkler tested. If travel lane spacings recommended for no-wind conditions are used, the water distribution pattern during winds will become uneven. If recommended lane spacing reductions for windy conditions are followed, the application pattern during winds may be acceptable under some wind directions; however, if winds are nearly parallel to the travel direction the application pattern will be poor. Also, if the narrower spacings recommended for winds are used, the application pattern may be poor if the wind velocity decreases. Spacings from 30 to 75 percent of the wetted diameter gave acceptable uniformity with no wind.

76:03F-049
ANATOMICAL RESPONSE OF POTATO STEMS AND ROOTS TO SOIL MOISTURE AND RATES OF FERTILIZER,
Singh, G., and Struchtemeyer, R.A.
Maine University, Department of Soils, Orono, Maine, 04473.
Agronomy Journal, Vol. 68, No. 5, p 732-735, September-October 1976. 4 tab, 14 ref.

Descriptors: Soil moisture, Soil water, Fertilizer, Fertilization, Nutrients, Potato, Nitrogen, Moisture stress, Root development, Xylem.

This study was conducted to determine the effect of three moisture regimes and three rates of fertilizer on the anatomy of stems and roots of the "Katahdin" cultivar of potato. A Caribou loam (coarse loamy, mixed frigid Dystric Eutrochrept) was used in a greenhouse experiment. The soil was placed in pots. Fertilizer at rates of 0, 168, and 336 kg N/ha, in a 10-15-15 mixture, was used. Soil moisture stresses equivalent to 30, 50, and 70 percent depeletions of available moisture were allowed to develop. The data showed that the area of the xylem in the stems decreased as soil moisture stress increased. The highest rate of fertilizer reduced the area of the xylem, but increased the diamter of the individual vessels. In the roots the area of xylem and phloem decreased while the area of cortex increased with an increase to soil moisture stress in the 75-day experiment. The area of xylem tended to increase while the cortical tissue tended to decrease with increases in the rate of fertilization.

76:03F-050
NEMATICIDE APPLICATION THROUGH POROUS SUBSURFACE IRRIGATION TUBING,
Chesness, J.L., Dryden, J.R., and Brady, U.E. Jr.
Georgia University, Department of Agricultural Engineering, Athens, Georgia.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 105-107, Special Edition 1976. 6 fig, 5 ref.

Descriptors: *Nematocides, *Nematodes, Subsurface irrigation, Irrigation practices, Irrigation systems.

The low translocation characteristics of Nemacur would not make it suitable for field application through a porous tube applicator. Vydate however, does offer some definite possibilities for field application through a porous tube applicator. Nematode populations are generally the highest in the surface or upper soil region. A lethal Vydate concentration (according to its manufacturer) is 5 ppm. This minimal concentration in the Vydate test was attained as far out as 60 cm horizontally (from the applicator) at a 23 cm depth. With multiple laterals on a 120 cm spacing the overlap effect in the water distribution pattern should provide a 5 ppm or greater Vydate concentration in a major portion of the soil profile. The above "field application inference" is just that; an inference based on laboratory tests. The affects upon the nematicide distribution patterns of higher initial soil water contents and reduced initial concentrations must be field evaluated before the inference label can be removed.

76:03F-051

SUBSURFACE AND FURROW IRRIGATION EVALUATION FOR BEAN PRODUCTION,
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Transactions of the American Society of Agricultural Engineers, Soil and Water, p 1089-1092, Special Edition, 1976. 4 fig, 3 tab, 19 ref.

Descriptors: *Subsurface irrigation, *Furrow irrigation, Irrigation, Irrigation practices, Beans, Crop production, Water conservation.

The water use efficiency, yields of beans and economic feasibility of furrow and subsurface irrigation systems were compared in field experiments. Subsurface irrigation required 55 percent less water to produce a yield of beans comparable to that obtained with furrow irrigation. Water use efficiencies of 81.9 and 37.5 kg of beans per cm of water were obtained for the treatments irrigated with subsurface and furrow irrigation systems, respectively. Spacing for subsurface irrigation laterals was obtained from a laboratory experiment and was 84 percent of the theoretical spacing. If the usable life of the porous pipe can be extended to 3 years, the price of the subsurface system could be comparable to that of the furrow irrigation system when water cost is $0.0135/cu m.

76:03F-052

EVAPOTRANSPIRATION AND WATER USE EFFICIENCY BY SOYBEAN LINES DIFFERING IN GROWTH HABIT
Singh, B.P., and Whitson, E.N.
Fort Valley State College, Division of Agriculture, Fort Valley, Georgia.
Agronomy Journal, Vol. 68, No. 5, p 834-835, September-October 1976. 2 fig, 4 ref.

Descriptors: *Soybeans, Evapotranspiration, Crop response, Canopy, Eddies, Crop production, Water vapor, Air circulation.

Determinate and indeterminate soybeans differ in canopy morphology due to a difference in their growth habits. Canopy morphology may affect receipt and loss of radiation, air circulation, and eddy turbulence. These factors may in turn influence heat and water vapor transfer, thereby possibly influencing plant water use. The objective of this study was to determine the effects of soybean growth habits on evapotranspiration and water use efficiency. The daily evapotranspiration rate for both lines was maximum at the early reproductive stage. Water extraction by both lines extended to a 122-cm soil depth, the lowest depth measured. The total evapotranspiration by the determinate line was 41.2 cm as compared to 39.2 cm for the indeterminate line. The difference in growth habits amounted to only a small fraction of the total evapotranspiration. The determinate line produced 24.9 percent more grain than the indeterminate line by utilizing only 5.6 percent more water. This accounted for an 18.1 percent greater water use efficiency of the determinate line. These values suggest that growth habits affect water use efficiency primarily by controlling grain yield.

76:03F-053

EVALUATION OF SLOW-RELEASE NITROGEN FERTILIZERS ON PENNPAR CREEPING BENTGRASS,
Waddington, D.V., and Duich, J.M.
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Agronomy Journal, Vol. 68, No. 5, p812-815, September-October 1976. 3 fig, 2 tab, 11 ref.

Descriptors: Fertilization, Nutrients, Turf grasses, Nitrogen, Urea, Crop production, Turf, Kentucky Blue Grass.

As new fertilizer materials become available for turfgrass fertilization, their relative merits should be evaluated under various field conditions so that sound recommendations can be made concerning their use. In this study on 'Pennpar' creeping bentgrass single applications of four slow-release N fertilizers and multiple applications of urea applied to fine, mixed, mesic Typic Hapludalf soil were compared for four consecutive growing seasons. Split applications of slow-release materials were also included in the fourth season. Clipping yields and turf color were used to evaluate response to fertilization. Growth patterns varied from year to year, but certain relationships between treatments generally remained the same: 1) greatest initial response occurred with isobutylidene diurea; 2) yields from slow-release treatments equalled or exceeded those from the urea treatment for 13 to 14 weeks, thereafter urea gave higher yields; 3) response from sulfur-coated urea and resin-coated fertilizer was intermediate between and ureaform. Split applications of slow-release sources reduced the flush of spring growth and increased turf color in the fall when single spring applications were used. The delay in response noted after isobutylidene diurea applications on Kentucky bluegrass in other experiments was not as apparent under the conditions of this study, possibly due to the incorporation of fertilizer by aerating and topdressing at the time of application and more liberal watering on the bentgrass area.

76:03F-054
RELATIONSHIP BETWEEN POTATO YIELD AND OXYGEN DIFFUSION RATE OF SUBSOIL,
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Agronomy Journal, Vol. 68, No. 5, p 823-825, September-October 1976. 1 fig, 1 tab, 24 ref.

Descriptors: Potatoes, Crop response, Crop production, Soil physical properties, Soil compaction, Organic matter, Soil properties, Soil moisture, Field capacity.

Numerous studies in the past have been made of the effects of soil compaction on patato yield by deliberately packing the soil in small experimental plots. Since information obtainable from such experiments has limited value in the economic assessment of crop production of an area, a study was conducted on 10 different farmer's fields to find out which soil physical property (or a combination of properties) may best define the prevailing productive capacity of a soil for potatoes. Various soil properties (stones, sand, silt, clay, bulk density, penetrometer readings, and organic matter) were measured according to the methods given by Black (1965) at a depth of 20 to 28 cm (8 to 11 inches) where the compact soles usually occur. Oxygen diffusion rate, however, was determined at a moisture content of field capacity by the platinum microelectrode method (Lemon and Erickson, 1952) using a rate meter manufactured by Jensen Instruments, Tacoma, Washington. Stepwise multiple regression analysis of potato yields of cultivar 'Netted Gem' and the soil properties indicated that oxygen diffusion rate of subsoil was one single factor which highly correlated with marketable yield ($r = +0.82$). The correlation coefficient was significant at the 1% level of probability. Further addition of other properties did not improve the r value significantly. The study indicates the oxygen diffusion rate of subsoil is useful criteria to diagnose the prevailing physical condition of the soil which in turn, could be related to the relative productive capacity of soil for potato production in New Brunswick, Canada.

76:03F-055
STOMATAL RESPONSE TO LEAF WATER POTENTIAL AS AFFECTED BY PRECONDITIONING WATER STRESS IN THE FIELD
Thomas, J.C., Brown, K.W., and Jordan, W.R.
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Agronomy Journal, Vol. 68, No. 5, p 706-708, September-October 1976. 4 fig, 13 ref.

Descriptors: Grain sorghum, Cotton, Crop response, Moisture stress, Stomata, Crop production, Irrigation, Irrigation Effects, Irrigation practices, Soil water.

Previous research has shown that stomatal response to decreasing soil water potential of chamber-grown sorghum and cotton posure to previous water stress. This work was undertaken to determine if stomatal response of field-grown plants is also altered by previous water stress. Stoneville 213 cotton was grown in the field under movable rainshelters and was subjected to three treatments: control -- well watered, one period of water stress, and two periods of water stress. After this preconditioning period, all plants underwent a final stress during which stomatal response to leaf water potential was measured. The periods of preconditioning water stress were characterized by decreased cumulative growth as measured by leaf area per plant. Leaf areas for the control, one soil water stress plant, and two soil water stress plants were 5,200, 2,200, and 1,200 sq cm, respectively. Lower stomates of preconditioned field-grown plants remained open to lower leaf water potentials (-28 to -30 bars) during the final stress than those of plants which were not preconditioned (-22 bars). These results were similar to those found previously on chamber-grown plants which had been exposed to more frequent but shorter stresses. The six to eight bar adjustment in leaf water potential versus stomatal resistance as a result of previous water stress indicates a need for caution in interpreting data from plants of unknown water stress history.

76:03F-056
SULFUR AND NITROGEN REQUIREMENTS OF SUGARCANE,
Fox, R.L.
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Agronomy Journal, Vol. 68, No. 6, p 891-896, November-December 1976. 9 fig, 3 tab, 25 ref.

Descriptors: Sugarcane, Nitrogen, Sulfur, Nutrients, Fertilizers, Fertilization

The internal S requirement of sugarcane is not well defined and there are no published data on the external SO1-S requirements. The objectives of this study were to provide data on sulfur distribution and N:S ratios in sugarcane. Sugarcane was grown in solution cultures and in potted soil material which provided several concentrations and ratios of NO3 and SO1 in solution. External S and N requirements were estimated from plots of yield vs. SO4 or NO3 concentrations in solution cultures and in artificial soil solutions. The external S requirements at age 35 days was about 9 ppm. After 70 days the requirement was about 5 ppm when N was adequately supplied. The external S requirement for early growth was 0.36% S in the whole plant and 0.24% for leaf blades 3 through 6. When plants were 70 days old, 0.10% S in leaf blades or 0.08% S in leaf sheaths was sufficient. Sulfur-deficient, field-grown sugarcane 18 months old contained 0.075% S in leaves 3 through 6 and 0.072% S in the corresponding leaf sheaths. Sulfur fertilized sugarcane contained 0.138% and 0.232% for the same tissues. Ratios N:S differed for various tissues of the same plant. Distribution of S in the plant may be a valuable tool for assessing the S status of sugarcane. When S is deficient, old leaf blades contain more S than corresponding leaf sheaths, and blades and sheaths of leaves 3 to 6 contain about equal concentrations of S. Good S nutrition was associated with an elevated concentration of S in leaf sheaths as compared with leaf blades.

76:03F-057
NITRIFICATION INHIBITOR WITH FALL-APPLIED VS. SPLIT NITROGEN APPLICATIONS FOR WINTER WHEAT,
Boswell, F.C., Nelson, L.R., and Bitzer, M.J.
Georgia University, Agricultural Experiment Station, Department of Agronomy, Georgia Station, Experiment, Georgia 30212
Agronomy Journal, Vol. 68, No. 5, p 7370740, September-October 1976. 1 fig, 5 tab, 11 ref.

Descriptors: Nitrification, Nutrients, Fertilization, Nitrogen, Crop response, Crop production, Wheat, Georgia, Soil analysis

Since numerous small grain producers desire to make fall application of efficient levels of N for maximum yields, studies are needed to determine the efficiency of fall-applied N (with and without an inhibitor) vs. split N applications. Field studies were conducted at two locations each year over a 3-year period with the objective of evaluating the response of wheat to N rates, time of application, and effect of a nitrification inhibitor on soils of different characteristics.

Yields, tissue concentrations of various elements, grain analyses, and soil NH4(-) and NO3(-)N were evaluated. Splitting the N, 28 kg/ha in the fall and 56 hg/ha topdressed in the spring, was superior to applying all the N in the fall. The inclusion of the nitrification inhibitor, 2-chloro-6-(trichloromethyl) pyridine (N-Serve), with ammonium sulfate in the fall at the rate of 84 kg/ha did not influence yields or N levels in the tissue or grain. The inhibitor had no effect on elements other than N. Although the nitrification inhibitor influenced the retention of the NH4(-)N in the soil until the January sampling, this retention was not evident for either soil at the March sampling. Therefore, we concluded that the N applied as a part of the complete fertilizer at the rate of 28 or even 84 kg/ha in the fall is inadequate for maximum wheat yield in either the coastal plain or piedmont regions of Georgia. A nitrification inhibitor applied with the ammonium sulfate was ineffective in preventing nitrification of the ammonium nitrogen or to increase yields.

76:03F-058

INFLUENCE OF NITROGEN, NARROW ROWS, AND PLANT POPULATION ON COTTON YIELD AND GROWTH

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Agronomy Journal, Vol. 68, No. 6, p 897-901, November-December 1976. 3 fig, 8 tab, 18 ref.

Descriptors: Cotton, Crop response, Fertilization, Fertilizers, Nitrogen, Plant population, Crop production

Narrow row planting of cotton has the potential for improving yield and production efficiency. Fertilizer needs and other production technology for narrow row cotton have received little attention, especially the nitrogen (N) requirement. The objective of this study was to ascertain if N fertilizer, narrow row, and high population, has any effect on growth and yield of dryland cotton. The relationship between petiole NO(-)3(-)N at various stages of development and yields was also investigated. Row spacing (25, 51, and 76-cm), plant populations (123,550 and 173,000 plants/ha), and N rate (0, 45, and 90 kg/ha) variables were placed in a factorial arrangement of a randomized, complete block design with four replications. Low N treatments (45 kg/ha) produced no significant change in yield, but higher N rates reduced yield significantly. The 25 and 51-cm row spacings produced significantly higher yield than 76-cm rows. The range of plant populations used did not materially affect yield, but there was a significantly N-population interaction. Narrow rows reduced plant height. NO(-)3(-)N levels in petioles increased with increased N rate, being highest at the square stage of plant growth and decreasing sharply at the flower and boll stages. There was no significant correlation between petiole NO(-)3(-)N and yield. Narrow row cotton can result in higher yield and is especially of interest where the length of growing season is not optimum.

76:03F-059

OPTIMUM CONTROL OF IRRIGATION WATER APPLICATION,

Fogel, M.M., Duckstein, L., and Kisiel, C.C.
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Journal of Hydrology, Vol. 28, No. 2/4, p 343-358, February 1976. 4 fig, 17 ref.
OWRT B-032-ARIZ(26)

Descriptors: *Irrigation water, *Management, *Mathematical models, *Decision making, *Optimization, Farms, Soil water, Hydrologic aspects, Stochastic process, Water costs, Methodology, Equations, Systems analysis, Forecasting.

Managing farm irrigation systems involves the choice of method, time, and quantity of irrigation water application. This paper focuses on the problem of continuous or periodic review of the factors that affect crop production (i.e., climate), that is, making decisions based on relatively short-term predictions. Finding the optimal irrigation policy is examined using a new approach based on the idea that an analogy exists between a business that stocks physical goods and a farm irrigation system in which the soil is a reservoir that stores water for future use by the plant. The demand on this reservoir may be either deterministic or stochastic. It is shown that inventory models can be adapted to the decisions involving the efficient operation of such farm irrigation systems.

76:03F-060

APPLICATION OF A TWO-VARIABLE MITSCHERLICH FUNCTION IN THE ANALYSIS OF YIELD-WATER-FERTILIZER RELATIONSHIPS FOR CORN

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Water Resources Research, Vol. 12, No. 1, p 6-10, February 1976. 4 fig, 3 tab, 6 ref.

Descriptors: Model studies, Fertilizers, Fertilization, Corn, Colorado, Kansas, Simulation analysis, Crop response, Nutrients, Crop production.

Variations of models developed by E.A. Mitscherlich in the early part of this century are periodically used for estimating input-output relationships for plants. Mitscherlich's work focused on a single variable. While these exponential models incorporate features of theoretical appeal, the procedures for quantifying the models are relatively complex when two or more independent variables are included. In fits of Mitscherlich and polynomical forms to yield-water-fertilizer data for corn grown under experimental conditions in Colorado and Kansas, test statistics for the polynomial forms are as good as or better than those for the more complex Mitscherlich models.

76:03F-061

COMPARISON OF MODIFIED MONTMORILLONITE TO SALTS AND CHELATES AS CARRIER FOR MICRONUTRIENTS FOR PLANTS: II. SUPPLY OF IRON

Navrot, J. and Banin, A.
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Agronomy Journal, Vol. 68, No. 2, p 358-361, March-April 1976. 2 fig, 5 tab, 7 ref.

Descriptors: Iron, Nutrients, Fertilizers, Fertilization, Copper, Zinc, Manganese, Clays, Tomatoes, Beans, Crop response.

Symptoms of iron deficiency appear very frequently in the calcarcous soils which represent a major part of the agricultural soils of Israel; therefore a search for novel carriers of iron is constantly conducted. Previous studies showed that Cu, Zn, and Mn, attached to modified montmorillonite, can effectively replace salts and chelates as carriers for micronutrient elements for plants. In this research, the effect of iron attached to montmorillonite clay on element uptake and yield of plants was compared to that of commonly used iron sulphate or EDTA and EDDHA chelates. In the greenhouse, beans were grown in two calcareous, iron deficient soils and were treated with either FeSO49 Fe(+3)-EDTA, Fe(+3)-EDDHA, or Fe(+2) bound to montmorillonite clay. The rates of iron added varied from 15 to 60 mg Fe/kg soil for the salt and 3 to 12 mg Fe/kg soil for the chelates and the clay forms. It was found that Fd(+2)-clay and Fe(+3) in chelates, added at equivalent rates, supplied iron in comparable amounts; FeSO49 added at the conventional rates which are five to ten times higher than that added as clay- and chelate-bound iron, caused similar or lower uptake and yields. Moreover, the slow release of iron from Fe-clay, even when supplied in high rates, prevented excessive iron uptake which otherwise, as in the case of the chelate FeEDDHA, interferred with plant development. It is suggested that iron attached to montmorillonite clay can be used as an efficient source of iron for plants grown in calcarous soils.

76:03F-062

COMPARISON OF MODIFIED MONTMORILLONITE TO SALTS AND CHELATES AS CARRIER FOR MICRONUTRIENTS FOR PLANTS: I. SUPPLY OF COPPER, ZINC, AND MANGANESE

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Agronomy Journal, Vol. 68, No. 2, p 353-358, March-April 1976. 4 fig, 7 tab, 16 ref.

Descriptors: Nutrients, Fertilizers, Fertilization, Copper, Zinc, Manganese, Clays, Tomatoes, Beans, Crop response

The purpose of the study was to compare the effectiveness of a novel micronutrient fertilizer, modified montmorillonite clay, to the conventionally used salts and chelates as carriers of micronutrients to plants. Three elements -- Cu, Zn, and Mn -- in combination in various rates, and in three forms, as sulphates, EDTA chelates, or attached to montmorillonite clay, where applied to two micronutrient deficient sandy soils. Tomato and beans were grown under controlled greenhouse conditions in the treated soils. The application of micronutrient elements, in all of the forms used, significantly increased plant yields. In addition, the supply of micronutrients significantly increased the elemental concentrations of the plants. However the highest concentration of elements found in the plants did not always correspond to the highest yields. Generally the lower levels of addition of combined micronutrients improved the growth conditions considerably and the higher ones were less effective. The clay carrier was similar to the expensive chelates and generally more efficient than the salts in element supply and this resulted in better yield responses. The optimal rate of application of the combined elements for dry yield production in tomato plants in the soils studied appeared to be: 0.5 mc Cu, 1.6 mg Zn, and 2.5 mg Mn per kg of soil for the clay and chelate forms and somewhat higher for the salts.

76:03F-063

LAND FORMING SYSTEMS TO IMPROVE WATER USE EFFICIENCY

Koelliker, J.K.
Kansas State University, Department of Agricultural Engineering, Manhattan, Kansas
Kansas Water Resources Research Institute, Manhattan, KWRRI Contribution No. 184, 70 p, November 1976. 14 fig, 11 tab, 44 ref, 3 append. OWRT A-068-KAN(2), 14-31-0001-5016.

Descriptors: *Land forming, *Terracing, *Soil moisture, *Kansas, *Water utilization, Groundwater recharge, Rainfall, Recharge, Wheat, Grain sorghum, Fallowing, Model studies, Demonstration watersheds, Crop production, Watershed management, Monitoring, Agricultural watersheds, Potential water supply.

Two years of operation of conservation bench terraces and level pans at Garden City, Kansas conclusive as to determining increased water use efficienty for crop production. Precipitation in both years was well below normal and little surface runoff occurred. Measurements of precipitation, watershed runoff and soil moisture in the top 2.3 m were monitored and used to calibrate a soil moisture budget simulation model for western Kansas. The model was calibrated with one year's data from a fallow watershed. Predicted total soil moisture content in the 2.1 m soil profile averaged within 2.4 percent of actual field values. The model was then used to estimate the potential for ground water recharge from conservation bench terraces over the period 1945-1974.

76:03F-064

NITROGEN NUTRITION AND YIELD OF SUGARCANE AS AFFECTED BY N-SERVE

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Agronomy Journal, Vol. 68, No. 2, 343-346, March-April 1976. 4 fig, 3 tab, 13 ref.

Descriptors: Sugarcane, Fertilizers, Fertilization, Nitrogen, Irrigation effects, Irrigation practices, Nitrification, Nutrients.

Very few experiments have been conducted to evaluate N-Serve formulated with N-fertilizer for sugarcane. N-Serve when formulated with N-fertilizer increased sugarcane yields in the Philippines and in Louisiana but failed to do so in Puerto Rico and in Mauritius. In view of the relatively few experiments conducted with N-Serve for sugarcane and the conflicting nature of the results, a pot experiment in drums and a field experiment were conducted to study the effect of N-Serve formulated with solid ammonium sulfate (AS) on sugarcane ('HJ 5741') yield, leaf N content, tillering, and on soil N. In the pot experiment two soils, a clayey loam and a loamy sand were used combined with a high and low irrigation treatment. There were two rates of AS with and without N-Serve. A control treatment was also included. N-Serve was applied at 2.5% of the weight of AS. In the field experiment on a sandy clay there were three rates of AS with and without N-Serve. A control treatment was also included. N-Serve was applied at a flat rate of 24 liter/ha.

76:03F-065

NON-UNIFORM INFILTRATION UNDER POTATO CANOPIES CAUSED BY INTERCEPTION, STEMFLOW, AND HILLING,

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Agronomy Journal, Vol. 68, No. 2, p 337-342, March-April 1976. 4 fig, 2 tab, 38 ref.

Descriptors: Sprinkler irrigation, Irrigation practices, Irrigation effects, Infiltration, Potatoes, Leaching, Soil water, Deep percolation, Model studies.

It is generally assumed that infiltration of sprinkler irrigation and rainfall under potato is uniform. However we observed non-uniform infiltration beneath the hills of sprinkler-irrigated potatoes grown on Plainfield loamy sand (Typic Udipsamment; sandy, mixed, mesic). The objective of this field study was to determine the effects of foliage interception and hilling on non-uniform infiltration, since concentrating water in local zones would increase deep drainage and nitrogen leaching. To do this we traced the rainfall and irrigation infiltration pattern with Rhodamine WT dye and collected the stemflow in stem collars. Throughfall of rainfall, the soil water content, and soil water tension also were measured. From 20 to 46% of the irrigation and from 4 to 23% of the rainfall on the canopy flowed down the stems. Stemflow increased the soil water content around the stems and moved Rhodamine dye deep beneath the soil surface. Deep movement of dye beneath the furrows was caused by runoff from the hills and by leaf drip from the outer foliage. The results obtained suggest that irrigation and fertilizer management could be improved by taking this non-uniform infiltration pattern into account. Smaller irrigations should improve water use efficiency and minimize nitrate leaching. Further, evaluation of solute movement by soil sampling should consider the spatial variation introduced by the non-uniform infiltration. Finally, predictive leaching models should account for non-uniform infiltration.

76:03F-066

EFFECT OF INCREASING FOLIAGE AND SOIL REFLECTIVITY ON THE YIELD AND WATER USE EFFICIENCY OF GRAIN SORGHUM,

Stanhill, G., Moreshet, S., and Fuchs, M.
The Volcani Center, Division of Agricultural Meteorology, Bet Dagan, Israel
Agronomy Journal, Vol. 68, No. 2, p 329-332, March-April 1976. 1 fig, 3 tab, 5 ref.

Descriptors: Grain sorghum, Crop production, Crop response, Water use efficiency.

The effect of increasing foliage and soil reflectivity on yield and water use efficiency of grain sorghum crops grown under arid conditions with stored soil water only, was studied during 3 years of randomized block field experiments. Suspensions of kaolin were sprayed on the soil and/or foliage at different growth stages to select the most effective placement and timing for the treatment. Soil-only applications were ineffective in increasing yields but canopy sprays resulted in an additional yield of 446 kg/ha, or 11% over the unsprayed controls, averaged over the 3 years of experimentation. The most effective period for foliage sprays started seven weeks after seedling emergence and ended 10 days later, immediately before the panicles emerged. During this period, known to be critical for sorghum grain yield response to water status, the yield response averaged 2 kg grain/1 kg kaolin applied. Neither the total seasonal water use nor the rate of soil water depletion was affected by the foliage reflectance treatment. It is concluded that under arid conditions, kaolin suspensions sprayed twice on the foliage of unirrigated grain sorghum crops during the prepanicle-emergency stage shows promise as an effective method of increasing grain yield.

76:03F-067

GROWTH AND MINERAL COMPOSITION OF RICE AT VARIOUS SOIL MOISTURE TENSIONS AND OXYGEN LEVELS,

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Agronomy Journal, Vol. 68, No. 2, p 325-329, March-April 1976. 8 fig, 16 ref.

Descriptors: Rice, Crop production, Crop response, Soil moisture, Soil water, Manganese, Iron, Phosphorus.

The better growth of rice in a flooded soil as compared to an upland soil has been attributed to the reducing conditions caused by submergence. No study has been carried out, however, in which the effects of the soil moisture status has been separated from the effect of the oxidation-reduction conditions on early growth and mineral composition of lowland rice was determined by growing plants in artificially packed soil columns maintained under different soil moisture tension and oxygen conditions. Since soil aeration is largely governed by the moisture status of the soil, this study was designed to separate these effects by subjecting the rice plant to different aeration conditions while at the same time attempting not to limit moisture supply. In one experiment different redox conditions were established by maintaining soil columns at soil moisture tensions ranging from 0 to 80 cm during growth of the plants. In a second experiment plants were grown at soil oxygen levels of 0, 3, 8, and 12% while soil moisture was maintained at 10 cm moisture tension. Vegetative growth of rice was greater under reduced conditions than under oxidized conditions in both experiments. The P concentration of the plant was much higher under reduced conditions than under oxidized conditions. Reduced conditions increased the solubility of P, Fe, and Mn in the soil although no consistent effect of reducing conditions on plant uptake of Fe and Mn was observed.

76:03F-068
WATER TRANSPORT IN WHEAT PLANTS IN THE FIELD,
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Commonwealth Scientific and Industrial Research Organization Division of Environmental Mechanics, P.O. Box 821, Canberra City, Australian Capital Territory, Australia
Agronomy Journal, Vol. 68, No. 2, p 297-303, March-April 1976. 5 fig, 5 tab, 27 ref.

Descriptors: Wheat, Transpiration, Evapotranspiration, Water vapor, Model studies.

Most previous studies of water transport in crops have been based on simplified models of plant anatomy and canopy transpiration. Usually changes in the water potential of a particular leaf have been related to the water loss from the whole canopy. We present a more detailed analysis of plant water transport which accounts for the spatial distribution of water flows and transpiration losses throughout the canopy, and use it to estimate flow resistances in different segments of the pathway. Micrometeorological measurements of the flux densities of water vapor in the canopy were used to infer water fluxes through roots, stem sections, leaves, and ears of wheat plants in the field. Simultaneous measurements of soil and leaf-water potentials permitted calculation of flow resistances in roots, stems, and leaves. The study shows clearly how the water loss from one part of the canopy influences the development of water potentials in other parts and points up the difficulties of simplified transport models.

76:03F-069
NUTRIENT UPTAKE BY CORN AND GRAIN SORGHUM SILAGE AS AFFECTED BY SOIL TYPE, PLANTING DATE, AND MOISTURE REGIME,
Fribourg, H.A., Bryan, W.E., Lessman, G.M., and Manning, D.M.
Tennessee University, Department of Plant and Soil Science, Knoxville, Tennessee 37916.
Agronomy Journal, Vol. 68, No. 2, p 260-263, March-April 1976. 4 tab, 6 ref.

Descriptors: Corn, Grain sorghum, Soil moisture, Soil water, Tennessee, Nutrients, Nitrogen, Phosphorus, Potassium, Calcium, Manganese, Fertilizers.

Few data have been published on whole-plant nutrient removal by silage crops as influenced by soil types and species. In order to quantify nutrient removals by corn and grain sorghum silage crops, early (30 April-15 May) and late (2-12 June) plantings of 'Funk G-4831' corn and 'AKS 614' sorghum were grown in 1969 in 34 environments on 12 soil types, two soils at each of six locations in Tennessee.

Non-irrigated plots of the two plantings were grown on all soils, and irrigated plots were added to five of the soils. The corn was harvested for silage when 80 to 90% of the kernels were dented, and grain sorghum when the oldest seeds were in the soft dough stage. Tissue samples were collected and analyzed for N, P, K, Ca, and Mg. Total seasonal uptake was calculated by multiplying percent composition of each element by dry matter yield/ha. Corn silage yields ranged from about 6 to 28 metric tons/ha, and sorghum silage yields ranged from about 7 to 18 metric tons/ha. Nutrient uptake generally increased linearly with yield. Mean total uptake of N, P, K, Ca, and Mg were, for corn silage, 192, 28, 144, 39, and 37 kg/ha; and, for grain sorghum silage, 169, 26, 143, 40, and 35 kg/ha, respectively.

76:03F-070
ESTIMATING EVAPORATION AND TRANSPIRATION FROM A ROW CROP DURING INCOMPLETE COVER,
Tanner, C.B. and Jury, W.A.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California
Agronomy Journal, Vol. 68, No. 2, p 239-243, March-April 1976. 2 fig, 2 tab, 25 ref.

Descriptors: Model studies, Evapotranspiration, Evaporation, Transpiration, Potatoes, Lysimeters, Crop response, Crop production.

In order to model the evapotranspiration (ET) from a crop with incomplete cover, the evaporation (E) is estimated separately from the transpiration (T) since E and T usually do not vary proportionately. Our objective was to develop and test an ET model based on the 'potential' E and T estimates that are consistent with the potential ET estimate. When E is less than the potential E (the falling rate phase), it is estimated by two approaches based on E falling as the square root of T; however, the model assumes transpiration is at the 'potential' rate. ET estimates during cover development of potato for 2 years were compared with lysimeter measurements. The standard error of estimate varied from 0.40 to 0.94 mm/day depending on the method for estimating E. The estimate of cumulative ET for 4 weeks varied from the lysimeter a maximum of 1 cm in 9.7 cm ET.

76:03F-071

YIELDS AND SUGAR CONTENT OF SUGARBEETS AS AFFECTED BY DEFICIT HIGH-FREQUENCY IRRIGATION,
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Agronomy Journal, Vol. 68, No. 2, p 231-234, March-April 1976. 2 fig, 5 tab, 7 ref.

Descriptors: Sprinkler irrigation, Sugar beets, Crop response, Crop production, Evapotranspiration, Irrigation effects, Irrigation practices, Irrigation engineering, Irrigation systems.

Installation and operating costs of irrigation systems are related to system capacity and amount of water applied. If sprinkler systems can be designed for less than usual peak evapotranspiration rates, initial costs will be less. If less water is applied, operating expenses will decrease. Previous work indicated that sugarbeets can be grown satisfactorily under high-frequency deficit irrigation (daily or more often at rates less than evapotranspiration) with soil water supplying part of the irrigation deficit. A field study was conducted, using solid-set sprinklers, with the objective of determining the minimum amount of irrigation water that must be applied during peak use periods to avoid reduction in sugar yields. Treatments involved irrigation each morning at rates equivalent to various proportions of evaporation the previous day from a Class A Weather Bureau pan. The soil indicates that with soils with adequate available waterholding capacity and crops that will tolerate deficit high-frequency irrigation, systems can be designed for less capacity and total water application may be reduced. Soil water will be used to reduce the irrigation deficit.

76:03F-072
SALINITY EFFECTS ON NITROGEN USE BY WHEAT CULTIVAR SONORA,
Jadav, K.L., Wallinhan, E.F., Sharpless, R.G., and Printy, W.L.
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Agronomy Journal, Vol. 68, No. 2, p 222-226, March-April 1976. 3 fig, 4 tab, 7 ref.

Descriptors: Nitrogen, Fertilizers, Fertilization, Nutrients, Wheat, Salinity, Saline soil, Crop production, Crop response.

The importance of N nutrition to fulfilling the high production potential of some semidwarf wheat cultivars under irrigation culture raises problems of balance between N and salinity. Inasmuch as growth may be limited in salt affected soils, thereby reducing total N requirement, the usual rates of fertilizer application may be excessive and thus contribute to the salinity problem. This study with 'Sonora 64' wheat was done to measure the effects of salinity and stand density on plant growth and grain yield, to estimate N uptake in relation to salinity and the stage of plant development, and to evaluate leaf-N as a basis for diagnosing the N status of the plant.

76:03F-073
LONG-TERM RESIDUAL FERTILITY AND CURRENT N-P-K APPLICATION EFFECTS ON SOYBEANS,
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Agronomy Journal, Vol. 68, No. 2, p 315-318, March-April 1976. 2 fig, 6 tab, 19 ref.

Descriptors: Soybeans, Fertilizers, Fertilization, Nitrogen, Phosphorus, Potassium, Legumes, Crop response, Crop production.

Soybean yield response to currently applied fertilizers, especially N, has been erratic while responses to residual P and K have been more consistent. This study was conducted to determine if residual N-P-K fertilizers applied over a period of years to other non-leguminous crops would influence soybean fertilizer requirements. Soybeans were planted on a Rarden sl soil where plots has received the same rates of P and K for 13 years. Previous N levels were 56 or 112 kg/ha, depending on the crop. Since legumes had not grown on the area for at least 16 years, significant responses to 56 kg/ha of N occurred each year at the high level of P and K. A greater yield response occurred from the P application than from K. The fertilizer times year interaction effects on yield was greatest for P as compared to N or K interactions when fitted to a regression model equation. The highest rates of N-P-K resulted in significantly larger soybean seed, better quality (seed index), and higher crude protein content than low N-P-K rates or control plots. Crude protein was inversely related to total oil content. Even though relatively high levels of P and K were applied to certain plots for 16 years and crop residues remained on the soil surface each year, high levels of extractable (double acid) P or K were not found in the soil.

76:03f-074
RELATIONSHIP BETWEEN NITROGEN ANALYSIS OF SOYBEAN TISSUES AND SOYBEAN YIELDS,
Pal, U.R. and Saxena, M.C.
Kentucky University, Department of Agronomy, Lexington, Kentucky 40506
Agronomy Journal, Vol. 68, No. 6, p 927-932, November, December 1976. 4 fig, 2 tab, 12 ref.

Descriptors: Nitrogen, Nutrients, Soybeans, Crop response, Fertilization.

In order to determine the applicability of N analysis of plant tissues as a diagnostic tool for N nutrition, it is essential to study the N status of soybean plants under varying N supply. Field experiments were conducted to determine the effect of N fertilization at the rates of 0, 25, 50, 100, and 200, and 300 different plant parts of nodulating (inoculated and uninoculated) and non-nodulating isolines of 'Clark' and 'Harosoy' soybeans at various stages of growth and to correlate the N status of soybean plants with yields.

76:03F-075
LEAF CONDUCTANCE RESPONSE TO HUMIDITY AND WATER TRANSPORT IN PLANTS,
Hall, A.E. and Hoffman, G.J.
California University, Department of Plant Sciences, Riverside, California 92502
Agronomy Journal, Vol. 68, No. 6, p 876-881, November-December 1976. 6 fig, 23 ref.

Descriptors: Stomata, Humidity, Leaves, Photosynthesis, Transpiration, Vapor pressure.

Stomatal response to humidity is a potentially important adaptive characteristic. The possibility that stomata may respond to humidity independently of changes in bulk leaf water status was tested. Also the basis for reported differences in leaf water potential response to transpiration was investigated. Simultaneous measurements of in situ leaf water potential, transpiration, and net photosynthesis were made in controlled environments using sunflower and pinto bean. Responses of leaf conductance and leaf water potential to changes in ambient humidity and root medium water potential were determined.

76:03F-076
EFFECT OF SOIL MOISTURE TENSION AND AMENDMENTS ON YIELDS AND ON HERBAGE N, P, AND S CONCENTRATIONS OF ALFALFA,
Canada Department of Agriculture, Research Station, Melfort, Saskatchewan, Canada SOE 1AO
Agronomy Journal, Vol. 68, No. 5, p 741-744, September-October 1976. 5 tab, 9 ref.

Descriptors: Alfalfa, Soil types, Nutrients, Soil moisture, Soil water, Soil texture, Crop response, Nitrogen, Phosphorus, Sulfur, Barley, Farm wastes.

Low protein concentration has been observed in alfalfa herbage grown in Gray Wooded Luvisol soils, particularly in cool, wet years. Nutrient deficiencies of N, P, and S also occur on these soils. The objectives of this experiment were to determine how soil moisture and soil type interact with amendments to increase yield and change N, P, and S concentrations in alfalfa herbage grown in the greenhouse. Three Gray Wooded Luvisols, Typic Cryoboralf (Arborfield clay, Garrick clay loam, Mollic Cryoboralf, and Waitville loam) and one Dark Gray Luvisol soil (Nipawin sandy clay loam) times two soil moisture tensions (100 and 151 millibars) were main treatments. Amendments of cattle manure, sedge peat, and wheat straw were applied on subplots at 2.5% of soil weight. Additional subplots of a control and ammonium nitrate were added. Yield of alfalfa was significantly related to moisture use. Moisture use by alfalfa was higher with cattle manure incorporated in the heavier textured Garrick clay loam and Arborfield clay soils than for other amendments or soil types. The manure treatment applied to Garrick clay loam and Arborfield clay soils under low soil moisture tension produced the highest herbage yields.

76:03F-077
YIELD AND NITROGEN UTILIZATION BY RICE AS AFFECTED BY METHOD AND TIME OF APPLICATION OF LABELLED NITROGEN,
Reddy, K.R. and Patrick, W.H. Jr.
Louisiana State University, Louisiana Agricultural Experiment Station, Department of Agronomy, Baton Rouge, Louisiana 70803
Agronomy Journal, Vol. 68, p 965-969, November-December 1976. 1 fig, 6 tab, 20 ref.

Descriptors: Nitrogen, Fertilization, Nutrients, Fertilizers, Rice, Crop response.

Recent increases in the cost of N fertilizer make it important to examine methods or improving the utilization of fertilizer N by lowland rice. The objective of the present investigations was to compare the effects of different methods and times of N application on yield and utilization of N by lowland rice. Field experiments using labelled fertilizer N were carried out during 1974 and 1975 utilizing different times and methods of application of ammonium sulfate on small field plots. Fertilizer N was applied either by deep placement at the beginning of the season or at one or more times during the growing season as surface application. Relative contributions of native soil N and fertilizer N sources to plant uptake were followed during the growing season, and total uptake of native soil N and fertilizer N by rice was determined at harvest.

76:03F-078
SCHEDULING CENTER PIVOT SPRINKLER IRRIGATION SYSTEMS FOR CORN PRODUCTION IN EASTERN COLORADO,
Heermann, D.F., Haise, H.R., and Mickelson, R.H.
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Transactions of the American Society of Agricultural Engineers, Soil and Water, p 284-287, Special Edition 1976. 6 fig, 1 tab, 2 ref.

Descriptors: Scheduling, Irrigation systems, Sprinkler irrigation, Irrigation, Corn, Colorado, Soil moisture, Crop production.

The United States Department of Agriculture Irrigation Scheduling Program was modified to probide multiple irrigation forecast dates for use with center pivot sprinkler irrigation systems. Four Eastern Colorado cooperators used the program and developed confidence in the computer output mailed to them weekly. Each cooperator used the information slightly differently. Some cooperators started the irrigation system at the earliest recommended date, whereas others started their systems between the 'start' and 'no later than' date. The two dates provided (a) the 'start' date when the soil water depletion was equal to the irrigation depth, and (b) the 'no later than' date when the system must be started so as not to deplete 50 percent of the available soil water at any location in the field. The cooperator who participated for 3 years reported that his yields had definitely increases due to the scheduling program. Thus, the scheduling program certainly can be beneficial to center pivot irrigation by increasing yields and conserving energy, water and fertilizer (in the deep percolation).

76:03F-079
SOIL WATER DEPLETION--YIELD RELATIONSHIPS OF IRRIGATED SORGHUM, WHEAT, AND SOYBEANS
Musick, J.T., New, L.L., and Dusek, D.A.
United States Department of Agriculture, Southwestern Great Plains Research Center, Department of Agricultural Engineering, Bushland, Texas
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 489-493, Special Edition 1976. 4 fig, 11 ref.

Descriptors: Soil water, Soil moisture, Irrigation, Irrigation effects, Grain sorghum, Wheat, Soybeans, Irrigation practices.

Approximately 4 billion cu m of groundwater is pumped annually to irrigate sorghum. wheat and soybeans grown in the fine-textured soils of the Southern High Plains. Declining groundwater storage and the high costs of pumping necessitate that water be applied only when it is needed to prevent appreciable yield reductions. Relationships between soil water depletion and grain yields provide a rational basis for scheduling irrigations based on soil water in the major root zone.

76:03F-080
COMPARISON OF SIMULATED AND MEASURED NITROGEN ACCUMULATION IN BURLEY TOBACCO,
Zartman, R.E., Phillips, R.E., and Leggett, J.E.
Texas Technical University, Department of Agronomy, Lubbock, Texas 79409
Agronomy Journal, Vol. 68, No. 2, p 406-410, March-April 1976. 4 tab, 13 ref.

Descriptors: Fertilizers, Fertilization, Nitrogen, Tobacco, Nutrients, Simulation analysis, Model studies, Root development.

Efficient utilization of N fertilizers by plants is important for scientific, economic, and environmental reasons. The objectives of this experiment were (1) to experimentally evaluate the simultaneous mass flow and diffusion of NO3(-)N to tobacco roots and (2) to compare the calculated accumulation of N in tobacco, the root of which was assumed to be a perfect sink for NO3(-)N (Model I), or flux of NO3(-)N into the root which was assumed to be proportional to concentration or NO3(-)N at the root surface (Model II), to measured accumulation of N in Burley tobacco grown under field conditions. Model I overestimated accumulation of N an average of 52%. Model II underestimated accumulation an average of 26%. The proportionality constant, k, assumed by Model II, was found to be 4.27 times 10 to the minus 7th power sq cm sec-1 throughout the growing season, except when moderate plant water stress was experienced by the plant. The data show that the accumulation of N by Burley tobacco was proportional to the concentration of NO3(-)N in the soil solution.

76:03F-081
SPRINKLER APPLICATION OF P AND ZN FERTILIZERS,
Hergert, G.W. and Reuss, J.O.
Nebraska University - North Platte Station, Department of Agronomy, North Platte, Nebraska
Agronomy Journal, Vol. 68, No. 1, p 5-8, January-February 1976. 2 fig, 7 tab, 9 ref.

Descriptors: Phosphorus, Zinc, Fertilizers, Fertilization, Nutrients, Sprinkler irrigation, Irrigation practices, Irrigation water, Corn.

The rapid development of sprinkler irrigation in the Great Plains has stimulated interest in applying fertilizers in sprinkler irrigation water. Sprinkler application and conventional preplant application effects of P and Zn fertilizers on the dry matter yield, nutrient content, and grain yield of corn were compared in 1968 and 1969. Both years preplant P treatments produced a significantly higher dry matter yield during the first 5 weeks of the growing season. No significant difference existed between P treatments after this time. In 1969 plants which received preplant P and Zn contained slightly higher concentrations of P and Zn than the plants which received sprinkler P and Zn. Grain yields were significantly increased by Zn application in 1968 but not in 1969. In 1968 on a Nunn clay loam soil the sprinkler-applied P did not move below a 4-5 cm depth. On a Haxtun loamy sand in 1969 sprinkler-applied P moved to a depth of approximately 18 cm. Sprinkler-applied Zn moved to a maximum depth of 5 cm on both soils.

76:03F-082
CORN GROWTH AS AFFECTED BY AMMONIUM VS. NITRATE ABSORBED FROM SOIL,
Dibb, D.W. and Welch, L.F.
Potash Institute, Department of Agronomy, 91 Pecos Avenue, Route 1, Columbia, Missouri 65201
Agronomy Journal, Vol. 68, No. 1, p 89-93, January-February 1976. 1 fig, 8 tab, 14 ref.

Descriptors: Ammonium, Nitrate, Corn, Crop response, Leaching, Denitrification, Greenhouse experiments, Absorption.

The effect of NH4 on corn growth in a soil medium is of interest because of the possibility of significantly decreasing leaching and denitrification losses of applied N by preserving N in the NH4 form. The objective of this investigation was to determine growth and nutrient content of corn plants when the principal form of N was either NH4 or NO3. Corn, grown in the greenhouse in a soil medium, was allowed to absorb N as either NH4 or NO3. A chemical nitrification inhibitor and different sources of added N were used to manipulate the form of N available for absorption. The maximum amount of N absorbed as NO3 was estimated as the difference between the NO3 content of fallow and cropped pots at harvest. Plants estimated to have absorbed at least 95% of their N as NH4.

76:03F-083
SUGARBEET YIELD AND QUALITY AS AFFECTED BY NITROGEN LEVEL,
Carter, J.N., Westermann, D.T., and Jensen, M.E.
Snake River Conservation Research Center, Department of Soil Science, Kimberly, Idaho 83341
Agronomy Journal, Vol. 68, No. 1, p 49-55, January-February 1976. 5 fig, 4 tab, 15 ref.

Descriptors: Sugar beets, Nitrogen, Nutrients, Fertilizers, Fertilization, Crop response, Idaho.

This study was conducted, under several climatic and soil conditions, to determine the effect of N level on sugarbeet yield and quality and to further develop and refine both soil and tissue test methods for predicting N fertilizer needs for efficient refined sucrose production. Previous studies indicate that N fertilizer needs for maximum sucrose production may be predicted by considering yield potential and all N sources. Sugarbeets were grown under field conditions at N fertilizer levels varying from - to 448 kg n/ha on six sites throughout southern Idaho to determine root yield, sucrose percentages, sucrose yield, impurity index, and plant N uptake in relation to the residual NO3(-)N, mineralizable N, fertilizer N, and petiole NO3(-)N. These experiments demonstrated that the N fertilizer needs of sugarbeets can be determined by relating the root yield potential to the measured residual NO3(-)N plus a measured or estimated mineralizable N level for an area. Optimum N level from all available soil and fertilizer sources has been found to vary between 5 to 6 kg/metric ton of beet roots produced.

76:03F-084

IRRIGATION SCHEDULES FOR SUGARBEETS ON MEDIUM AND COARSE TEXTURED SOILS IN THE NORTHERN GREAT PLAINS,

Cassel, D.K. and Bauer, A.
North Carolina State University, Department of Soil Science, North Carolina
Agronomy Journal, Vol. 68, No. 1, p 45-48, January-February 1976. 1 fig, 3 tab, 5 ref.

Descriptors: Sugar beets, Soils, Soil investigations, Soil water, Soil moisture, Irrigation, Irrigation water, Tensiometers, North Dakota.

An increase in the access to irrigation water in the Northern Great Plains is effecting large increases in the acreages of soils being irrigated. Much of this water is being applied to medium to coarse-textured soils which hold a maximum of 7 to 12 cm of available water in a 152 cm deep profile. An investigation was conducted in the field to devise a system, using tensiometers, to schedule the application of irrigation water to sugarbeets growing on these soils. Tensiometers were installed at various soil depths, and irrigation water was applied with a small plot irrigator when soil moisture tension reached a predetermined level. One tensiometer located at the 45 cm depth was equally effective in scheduling as two tensiometers, one positioned at a depth of 30 and one at 61 cm. Maximum crude sugar yields of 8.4 to 8.8 metric tons/ha were obtained in 1971 and 1973, respectively. Total water use efficiency was 0.15 to 0.16 metric tons of crude sugar/ha per cm. The maximum irrigation water use efficiencies were 0.32 and 0.36 for 1971 and 1973, respectively. It is concluded that 56 to 62 cm of water, well distributed throughout the growing season, is sufficient for sugarbeet production in southeastern North Dakota in a year of normal growing season temperatures.

76:03F-085

NITROGEN RELEASE FROM ISOBUTYLIDENE DIUREA: SOIL pH AND FERTILIZER PARTICLE SIZE EFFECTS,

Hughs, T.D.
Illinois University, Department of Horticulture, Urbana, Illinois 61801
Agronomy Journal, Vol. 68, No. 1, p 103-106, January-February 1976. 6 fig, 6 ref.

Descriptors: Nitrogen, Nutrients, Fertilizers, Fertilization, Soil moisture, Soil properties, Soil investigations, Urea, Nitrification.

Soil-isobutylidene diurea (IBDU) mixtures were incubated to determine the effects of soil pH and IBDU particle size on N release patterns. Such information is needed for predicting rates and frequencies of application. All incubations were conducted at a temperature of 21 ± 0.5 C and 28 ± 2% soil moisture. Evidence was obtained for excluding nura-N concentrations from calculations of N recovery, thus all recoveries were based on concentrations of (NH(+)4 + NO(-)3)(-)N. Nitrogen release patterns from 0.7 to 0.8 mm IBDU particles in soil at initial pH's of 5.7, 6.8, and 7.7 were determined. After four weeks of incubation, the amount of N released was equivalent to one-third of the IBDU-N for soil at pH 5.7, however, lesser amounts were released in soil at pH's 6.8 and 7.7. Differences in N release were due to differences in NH(+)4(-)N concentrations, whereas concentrations of NO(-)3(-)N were not related to soil pH throughout the 10-week incubation period.

76:03F-086
NUTRIENT UPTAKE BY RUSSET BURBANK POTATOES AS INFLUENCED BY FERTILIZATION,
Jackson, T.L. and Carter, G.E.
Oregon State University, Department of Soil Science, Oregon Agricultural Experiment Station, Corvallis, Oregon 97331
Agronomy Journal, Vol. 68, No. 1, p 9-12, January-February 1976. 5 tab, 11 ref.

Descriptors: Nutrients, Fertilizers, Fertilization, Potatoes, Zinc, Manganese, Oregon.

Zinc and Mn deficiencies have been observed frequently in potatoes grown on eastern Oregon soils developed under arid conditions. The study was designed to evaluate effects of band and broadcast applications of ammonium sulfate (AS) and monocalcium phosphate (MCP) on yield and uptake of P, Zn, and Mn by Russet Burbank potatoes grown on calcareous mineral soil deficient in N, P, Zn, and Mn. Potatoes were grown under field conditions, harvested and evluated. Fertilizer treatments were broadcast before planting and rototilled or banded at planting. Petiole samples to identify nutrient concentrations were taken when tubers were 2 cm in diameter. Whole plants were harvested 3 weeks later to measure nutrient uptake. Petiole concentrations and plant uptake of both Zn and Mn were greater when AS was banded than when broadcast, with or without band applications of Zn and Mn.

76:03F-087
RESPONSES OF THREE PEANUT CULTIVARS TO GYPSUM,
Walker, M.E., Keisling, T.C., and Dresler, J.S.
Coastal Plain Experiment Station, Department of Agronomy, Tifton, Georgia.
Agronomy Journal, Vol. 68, No. 3, p 527-528, May-June 1976. 2 tab, 12 ref.

Descriptors: Calcium, Gypsum, Crop response, Soil investigations, Nitrogen.

The differential response of peanut cultivars to soil applications of Ca has been established for many years. Recent research reports, however, have indicated that peanut cultivars respond similarly to Ca application. This may result in part from new peanut cultivars differing in their response to Ca. Experiments were therefore conducted on a low Ca soil to measure responses of three commonly grown peanut cultivars to soil-applied Ca. Results from this experiment show that gypsum had no effect on yield or sound mature kernels of Florunner peanuts. Florunner peanuts produced higher yields and grades than Florigiant or NC-Fla 14, regardless of treatments. Gypsum application to Florigiant and NC-Fla 14 peanuts increased yields, sound mature kernels, and extra large kernels. In general, gypsum increased the % oil in all cultivars. Florigiant contained less oil than the other cultivars. Nitrogen content of the seed of all cultivars was reduced by gypsum application. These data indicate that on low Ca soils Florunner peanuts can produce higher yields and quality with or without gypsum, while Florigiant and NC-Fla 14 need gypsum fertilization to increase yield and improve quality.

76:03F-088
NITROGEN AVAILABILITY TO WHEAT AS AFFECTED BY DEPTH OF NITROGEN PLACEMENT,
Daigger, L.A. and Sander, D.H.
Nebraska University, Department of Agronomy, Panhandle Station, Scottsbluff, Nebraska
Agronomy Journal, Vol. 68, No. 3, p 524-526, May-June 1976. 4 fig, 10 ref.

Discriptors: Nitrogen, Wheat, Fertilization, Fertilizers, Crop production, Nebraska, Soil moisture.

The availability of residual N in the root zone greatly influences the amount of N fertilizer required to optimize winter wheat yields. In order to determine the availability of N at different depths in the root zone, and N placement study was conducted in the field on two soils in western Nebraska, a deep alluvial fine sandy loam and a loess-derived silt loam. Ammonium nitrate was placed on the soil surface and at depths of 30, 60, 90, 120, and 150 cm. Wheat plants were harvested six times during the spring growing season to determine N uptake. Soil moisture was at field capacity in the spring when experiments were established. While N uptake tended to decrease as the depth of N application increased, total dry matter production was not affected by depth of N placement. Wheat plants easily obtained N placed at depths of up to 150 cm. The results indicate winter wheat roots are mostly established during the fall growing season and are in a position to provide N early in the spring for rapid above ground growth.

76:03F-089

DEFOLIATION AND FERTILIZER NITROGEN EFFECTS ON NITRATE-NITROGEN PROFILES IN MAIZE,
Hicks, D.R. and Peterson, R.H.
Minnesota University, Department of Agronomy and Plant Genetics, St. Paul, Minnesota 55108
Agronomy Journal, Vol. 68, No. 3, p 476-478, May-June 1976. 3 fig, 10 ref.

Descriptors: Corn, Hail, Nitrate, Nitrogen, Fertilization

Corn vegetative tissue remaining after hail damage is often utilized for forage. Environmental stresses may cause levels of nitrate-nitrogen in plant tissue that are toxic to ruminants. This study was conducted to determine the effect of leaf blade removal (simulated hail damage) and N fertilization of the soil on the NO-3-N profile of corn fodder. Leaf blade removal of 0, 50, 100% was imposed at tasseling on the corn hybrid 'Dekalb XL45A' grown in soil fertilized with either 115 or 230 kg N/ha. Plants were sampled approximately weekly for 6 weeks after defoliation.

76:03F-090
EVALUATION OF SULFUR-COATED UREA (SCU) APPLIED TO IRRIGATED POTATOES AND CORN,
Liegel, E.A. and Walsh, L.M.
Wisconsin University, Department of Soil Science, Madison, Wisconsin.
Agronomy Journal, Vol. 68, No. 3, p 457-463, May-June 1976. 4 fig, 5 tab, 9 ref.

Descriptors: Potatoes, Corn, Nitrogen, Fertilizers, Fertilization, Wisconsin, Leaching, Irrigation, Irrigation effects, Urea.

Excessive rates of soluble N fertilizers are sometimes used on irrigated sands in Central Wisconsin to compensate for loss of some of the applied N by leaching. Use of a slow-release form of N or several small applications of a soluble N fertilizer may eliminate some leaching and subsequent loss of NO3-N. This study was designed to evaluate these methods of reducing N losses by measuring yield and recovery of applied N by potato tubers and corn grain. Supplemental N treatments applied each year for 3 years were as follows: 1) urea in a single or split application, 2) SCU impregnated with a wax coating, and 3) SCU with only a sulfur coating.

76:03F-091
SALT TOLERANCE OF PROSTRATE SUMMER CYPRESS (KOCHIA PROSTRATA),
Francois, L.E.
Agricultural Research Service - United States Department of Agriculture, United States Salinity Laboratory, P. O. Box 672, Riverside, California 92502.
Agronomy Journal, Vol. 68, No. 3, p 455-456, May-June 1976. 2 tab, 9 ref.

Descriptors: Salinity, Saline soils, Salt tolerance, Greenhouse experiments, Sodium, Chloride, Rangelands.

Prostrate summer cypress, a widely distributed perennial shrub in Russia, was imported into the USA to determine its potential as an acceptable forage on the western rangelands. Since considerable acreage of its possible habitat contains salt-affected soils, a salt tolerance study was done to determine how well suited it was to these saline areas. Two accessions of prostrate summer cypress were tested using soil cultures in the greenhouse. Salinity levels used were 2, 7, 11, and 17 mmhos/cm. The plants were harvested six times over a 3-year period. Both accessions proved to be very salt tolerant but one was significantly more productive than the other at all salinity levels. Although sodium and chloride contents approached 50 and 85 meq/100 g dry matter, respectively, no salt injury symptoms were visible. Sodium uptake increased proportionately with increasing salinity, whereas chloride uptake was less dependent on salt concentration and appreciably greater than that of sodium. Since both accessions proved to be highly salt tolerant, they should be well adapted for planting in the salt-affected western rangelands.

76:03F-092

SEED COATING, PRECISION PLANTING, AND SPRINKLER IRRIGATION FOR OPTIMUM STAND ESTABLISHMENT,

Robinson, F.E. and Mayberry, K.S.
California University, Cooperative Extension, Department of Water Science and Engineering, California
Agronomy Journal, Vol. 68, No. 4, p 694-695, July-August 1976. 2 tab, 7 ref.

Descriptors: Lettuce, Sugar beets, Sprinkler irrigation, Germination, Carrots, Onions, Seeds, Irrigation effects, Irrigation practices.

The legal prohibition of the short handled hoe in California has forced a change in the conventional practice of surplus-seedling and subsequent thinning to achieve optimum stands with lettuce and sugar beet crops. Precision placement of coated seed was evaluated as an alternate method of stand establishment with five crops grown on Meloland sandy clay loam with sprinkler irrigation. Germination was compared to emergence of coated seed. Emergence was: carrot 86%, onion 85%, and sugar beet 71%. Single lettuce seeds 38 cm apart had 89% stand, paired seeds 2.5 cm apart on 38 cm intervals and thinned had 97%.

76:03F-093

CHANGES IN TOTAL N, ORGANIC MATTER, AVAILABLE P, AND BULK DENSITIES OF A CULTIVATED SOIL 8 YEARS AFTER TAME PASTURES WERE ESTABLISHED,

White, E.M., Krueger, C.R., and Moore, R.A.
South Dakota State University, South Dakota Agricultural Experiment Station, Department of Plant Science, Brookings, South Dakota 57006
Agronomy Journal, Vol. 68, No. 4, p 581-583, July-August 1976. 2 tab, 9 ref.

Descriptors: Nitrogen, Organic matter, Phosphorus, Bulk density, Soil investigations, South Dakota, Pastures, Alfalfa.

Cultivated Williams loam soils in north-central South Dakota were sampled after pastures were established and 8 years later so that the effect of the pastures on soils could be studied from analysis in the laboratory. Pastures were seeded to Russian wildrye, crested wheatgrass, or a mixture of smooth bromegrass, intermediate wheatgrass, and a pasture alfalfa. Soil N and bulk densities increased as available P decreased in the 8 years. The soil organic matter increased under all pastures, but it was small. The increases in organic matter, decreases in available P, and increases in saturated-clod bulk densities were different in the various pastures. Total N and organic matter increased about 0.001 and 0.02% per year, respectively, which is slower than the rate of decrease caused by cultivating the original grassland soils.

76:03F-094

EFFECT OF LEAF SHAPE ON RESPONSE OF COTTON TO PLANT POPULATION, N RATE, AND IRRIGATION,

Rao, M.J. and Weaver, J.B. Jr.
Georgia University, Department of Agronomy, Athens, Georgia 30602.
Agronomy Journal, Vol. 68, No. 4, p 599-601, July-August 1976. 4 tab, 8 ref.

Descriptors: Leaves, Cotton, Crop response, Irrigation, Irrigation practices, Nitrogen, Fertilization.

Leaves varying in shape have been identified in cotton, and it has been conjectured that leaf shape affects growth and other quantitiative characters in Upland cotton. The objective of these studies was to evaluate okra and normal leaf shape on boll rot, yield, earliness, boll size, and fiber properties. Near isogenic lines of okra and normal leaf shape cotton was evaluated at three plant populations and three N rates on an Appling coarse sandy loam soil over a 3-year period 1971-73. In 1972 irrigation treatments were also included. No significant interactions were found between leaf characters, plant populations, N rates, and irrigation. Okra leaf shape increased earliness, boll size, and micronaire and decreased seed cotton loss due to boll rot. With increasing plant populations, lint yield and earliness tended to increase and boll size decreased. Higher boll rot loss was observed at higher levels of N. Irrigated cotton produced significantly greater lint yield, boll size, and fiber length and increased earliness.

76:03F-095
HIGH-FREQUENCY TRICKLE IRRIGATION AND ROW SPACING EFFECTS ON YIELD AND QUALITY OF POTATOES,
Phene, C.J. and Sanders, D.C.
Agricultural Research Service-United States Department of Agriculture, Florence, South Carolina 29501
Agronomy Journal, Vol. 68, No. 4, p 602-607, July-August 1976. 6 fig, 4 tab, 15 ref.

Descriptors: Potatoes, Irrigation, Irrigation practices, Crop production, Soil water stress, Soil water, Soil moisture.

Soil water is a major limiting factor in the production and quality of potatoes. The objectives of this research were to determine the effects of trickle irrigation under controlled soil matric potential and two row spacings on the yield, quality, and nutrient contents of potatoes. Potatoes, trickle irrigated with nutrient solution and grown in 100-cm rwo spacing on sandy loam soil, yielded 76% more marketable potatoes than those trickle irrigated under a plastic mulch and grown on twin row spacing and 206% more than 100-cm spaced, nonirrigated potatoes.

76:03F-096
LATE SUMMER IRRIGATION AND ESTABLISHMENT OF WINTER ANNUAL LEGUMES IN A MEDITERRANEAN-TYPE CLIMATE,
Taggard, K.L., Delmas, R.E., and Raguse, C.A.
California University, Department of Agronomy, Davis, California.
Agronomy Journal, Vol. 68, No. 4, p 674-677, July-August 1976. 3 tab, 7 ref.

Descriptors: Legumes, Clovers, Grasses, Ryegrass, Irrigation, Irrigation effects, Irrigation practices.

Winter annual legumes have low fall and early winter forage yields in Califormia's Mediterranean-type climate. A 2-year field study was conducted to determine the effects of late summer irrigation on seedling development, forage yield potential, and management problems of subterranean clover, rose clover, and bur clover. A mixture of three annual grasses, slender wild oats, and annual ryegrass, and a natural stand of indigenous species were included in the study for comparison. By irrigation prior to fall rains, we subjected six successive seedings, 2 weeks apart, to higher temperatures and longer fall-growth periods than usual.

76:03F-097
SOYBEAN ROOT DEVELOPMENT AND SOIL WATER DEPLETION,
Stone, L.R., Teare, I.D., Nickell, C.D., and Mayaki, W.C.
Kansas State University, Department of Agronomy, Evapotranspiration Laboratory, Manhattan, Kansas 66506
Agronomy Journal, Vol. 68, No. 4, p 677-680, July-August 1976. 6 rig, 14 ref.

Descriptors: Soybeans, Root development, Soil moisture, Soil water, Model studies.

We conducted a field study to investigate soybean root growth and water depletion patterns. Field water depletion and rooting data are needed to assist in developing and refining models that consider root-soil-water interactions. Irrigated and nonirrigated soybeans were grown in a deep, barrier-free, Muir silt loam. Soil water content, determined using neutron moderation, was used to calculate water depletion rates. Soil water content and desorption curves were used to estimate soil water potential. Available soil water was estimated using--15 bars soil water potential as the lower limit of availability. We collected soil volumes 76 cm wide, 7.6 cm thick, and 180 cm deep and washed roots free using a 53-mesh screen. During the first half of our study, maximum root and water depletion depths were nearly equal. Later, water depletion tended to be about 15 cm deeper than root growth (possibly as a result of upward water movement into the water-depleted root zone).

76:03F-098
IRRIGATED AND NONIRRIGATED SOYBEAN, CORN, AND GRAIN SORGHUM ROOT SYSTEMS,
Mayaki, W.C., Stone, L.R., and Teare, I.D.
Kansas State University, Evapotranspiration Laboratory, Manhattan, Kansas 66506.
Agronomy Journal, Vol. 68, No. 3, p 532-534, May-June 1976. k fig, 1 tab, 4 ref.

Descriptors: Root distribution, Irrigation, Irrigation effects, Soybeans, Corn, Grain sorghum, Furrow irrigation, Soil water.

Knowledge of rooting patterns of various crops is important in designing irrigation systems and assessing water extraction capabilities. We investigated root depth and distribution under irrigated and nonirrigated conditions for soybeans, corn, and grain sorghum. Soil cores 6.7 cm in diam. were taken to 180 cm deep in the crop row, 1/4 row, and 1/2 row (furrow) for each crop at physiological maturity. The cores were sectioned in 30-cm increments and washed through 35-mesh screen (0.73 mm opening), and the roots oven dried. The study soil was deep, barrier-free, Muir silt loam (fine-silty, mixed, mesic, Pachic Haplustoll). Approximately 71, 64, and 86% of the total root dry matter were in the upper 30 cm for nonirrigated soybeans, corn, and grain sorghum, respectively. Only corn did not have roots in the 150 to 180-cm zone. Seasonal water uses under irrigated conditions (neglecting water flux into or from the root zone) were 65 cm, 65 cm, and 53 cm in soybeans, corn, and grain sorghum, respectively. Seasonal water use was approximately 44 cm by each of the three crops under nonirrigated conditions.

76:03F-099
EVALUATION OF NONUNIFORMITY IN IRRIGATION AND YIELD,
Varlev, I.
Academy of Agricultural Sciences, Agrophysics Laboratory, Sofia, Bulgaria
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR1, p 149-164, March 1976. 6 fig, 1 tab, 15 ref.

Descriptors: Irrigation, Irrigation effects, Irrigation practices, Irrigation efficiency, Crop production, Infiltration, Uniformity coefficient.

The nonuniformity of water distribution over an irrigated area is one of the basic features for evaluation of irrigation quality. It has been established, that nonuniformity of distribution influences crop yield from different parts of an irrigation water distribution and its' effect on crop yield and average infiltrated depth. For definite relationships between the depth of infiltrated water and yield crop, for arid, humid, and subhumid zones, a coefficient of the nonuniformity is defined, characterizing both nonuniformity and yield depression caused by nonuniformity of irrigation-water distribution.

76:03F-100
WATER MOVEMENT IN SOIL FROM TRICKLE SOURCE,
Hachum, A.Y., Alfaro, J.F., and Willardson, L.S.
Utah State University, Department of Agricultural and Irrigation Engineering, Logan, Utah.
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR2, p 179-192, June 1976. 9 fig, 3 tab, 10 ref.

Descriptors: Soil water movement, Soil water, Soil moisture, Soils, Soil investigations.

Trickle irrigation basically involves the slow application of water to the soil at particular points where the water immediately enters the soil and spreads through it without appreciable flow of free water on the soil surface. One of the basic research needs at the present time is to obtain more information about the water distribution pattern under a trickle source for different soil types and different discharge rates. The soil type and rate of water application influence the rate of horizontal and vertical water movement in the soil and the distribution of the water potential in the wetted soil zone. Efficient design, operation, and management of a trickle irrigation system require a full understanding of these factors. The objective of this research was to: (1) Study water movement and distribution in homogeneous soil profiles under various rates of water application from a surface trickle line source; and (2) utilize the results for practical use.

76:03F-101
CONSERVATION TILLAGE - EFFECTS ON CROP PRODUCTION AND SEDIMENT YIELD,
Mannering, J.V., Johnson, C.B., and Wheaton, R.Z.
Purdue University, Agronomy Department, Lafayette, Indiana.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 16 p, 11 tab, 10 ref.

Descriptors: Soil erosion, Crop response, Crop production, Erosion, Corn, Soybeans.

Although tillage systems that leave appreciable crop residues on the surface effectively reduce soil erosion, they can result in reduced crop yields on poorly drained soils. Data are presented that illustrate the erosion control effectiveness of various tillage systems following corn and soybeans.

76:03F-102
ENERGY (HOT WATER) STORAGE IN GROUNDWATER AQUIFERS,
Ebeling, L.L. and Reddell, D.L.
Texas A and M University, Department of Agricultural Engineering, College Station, Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 27 p, 7 fig, 1 tab, 26 ref.

Descriptors: Groundwater, Groundwater aquifers, Model studies, Aquifers, Groundwater management, Energy conversion, Energy.

A concept of storing hot water produced by solar collectors during the summer in groundwater aquifers is presented. The hot water would be pumped to the surface and used for space heating during the winter. The quantity of hot water capable of being produced at various areas in Texas and the aquifer availability for hot water storage is discussed. A numerical model to evaluate heat and mass transfer in the aquifer is developed.

76:03F-103
VERY-LOW-PRESSURE SPRINKLE IRRIGATION,
Burt, C.M. and Keller, J.
Utah State University, Department of Agricultural and Irrigation Engineering, Logan, Utah.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 24 p, 8 fig, 4 tab, 4 ref, 1 append.

Descriptors: Sprinkler irrigation, Irrigation, Irrigation systems, Irrigation practices, Irrigation engineering.

Tests were conducted on the available sprinklers which can be operated at pressures of less than 4/3 atmosphere. Operating characteristics and design recommendations for the 'best sprinkler' from each of the four types of very-low-pressure, VLP, sprinklers are presented. The four types include: spray heads, perforated pipe, reaction rotated sprinklers, and impact rotated sprinklers. The impact sprinkler appears to be superior for VLP operation and merits further developmental effort.

76:03F-104
FOOD PRODUCTION POTENTIAL FROM HOME GARDENS,
Smith, S.W. and Walker, W.R.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 11 p, 3 fig, 2 tab, 5 ref.

Descriptors: Food abundance, Foods, Mulching.

Developments in American agriculture are often applicable to home gardens. Technologies such as drip irrigation, mulching with black polyethylene sheeting, and intensive cultivation practices may be utilized by the gardener. Through these technologies the necessary labor input can be minimized and even a small garden can materially offset a family's food budget.

76:03F-105
GRASSLAND RENOVATION - CONSERVES SOIL AND ENERGY AND INCREASES RETURNS FROM GRASS FIELDS,
Smith, E.M. and Evans, J.K.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 12 p, 1 fig, 3 tab, 14 ref.

Descriptors: Grasslands, Soil erosion, Fertilization, Nitrogen, Legumes.

A grassland renovation seeder has been developed to interseed legumes into existing grass fields. This seeder disturbs less than ten percent of the grass sod. Most of the sod remains to prevent soil erosion, even on steep slopes. Grass fields which were renovated with a grassland renovation seeder by planting 6 pounds of red clover seed per acre required an energy investment of 0.023 times 1,000,000 KCal. per acre each year. Nitrogen fertilization of grass fields requires an energy input of 55 KCal. as compared with each KCal. of energy input when the new grassland renovation unit is used instead of nitrogen. Potential returns in the form of beef produced on the grass fields per 100 brood cows was increased from 25,272 pounds with nitrogen fertilization to 40,112 pounds with grassland renovation to obtain a clover grass mixture. Grassland renovation yielded 1.59 pounds of beef for each pound with nitrogen fertilization.

76:03F-106
THE CORNER SYSTEM - A VARIABLE RADII CENTER PIVOT SYSTEM,
Frankenstein, R.L.
Valmont Industries, Incorporated, Irrigation Products Division, Valley, Nebraska.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 12 p, 5 fig.

Descriptors: *Sprinkler irrigation, Irrigation practices, Irrigation systems, Irrigation efficiency, Irrigation engineering.

A center pivot irrigation system has been developed that distributes water considerably beyond the reach of previous center pivots; thus, allowing the irrigation of square, rectangular, and other non-circular field shapes. The system consists of an additional 'swing span' attanced to the end of the basic center pivot that extends and retracts to conform to field boundaries. The additional pipeline, the swing span, is supported by one steerable drive unit that is guided around the field, in and out of corners, by tracking a signal emitted by a buried signal wire. Sprinklers along the swing arm are controlled automatically to provide uniform water distribution under all parts of the system. This new concept of self-propelled irrigation allows over 96% field coverage in most situations.

This paper discusses the varicus technologies that were utilized in developing the 'Variable Radii Center Pivot System'.

76:03F-107
NEW 'LATERAL MOVE' SPRINKLER CUTS NO CORNERS,
Schleicher, J.
Irrigation Age Magazine, 1999 Shepard Road, Saint Paul, Minnesota.
Irrigation Age, Vol. 11, No. 1, 3 p, September 1976. 3 fig.

Descriptors: Sprinklers, Sprinkler irrigation, Irrigation, Irrigation practices.

A new sideroll sprinkler system has been developed to irrigate corn.

76:03F-108
OPTIMIZATION OF SUBUNIT DIMENSIONS FOR PRESSURIZED IRRIGATION SYSTEMS,
Oron, G., Karmeli, D., and Walker, W.R.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 11 p, 4 fig, 3 equ, 4 ref.

Descriptors: Optimization, Irrigation, Irrigation design, Irrigation systems, Pipelines, Piping systems, Model studies, Computer models.

The sophistication in analyzing optimality in a pressurized irrigation system design has evolved from pipe sizing problems for complex evaluations of layout alternatives, field dimensions, energy input, and operational criteria. The nonlinear, mixed-integer model developed gave interesting results to the more general design questions, but its complexity precludes its use as a design tool for many design applications, particularly where certain assumptions on field layout have been made. Results given in this paper demonstrate two of the possible uses a model like this may find feasible.

76:03F-109
ANALYSIS OF HIGH FREQUENCY FURROW IRRIGATION,
Walker, W.R. and Gerards, J.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 12 p, 5 fig, 2 tab, 9 equ.

Descriptors: Furrow irrigation, Surface irrigation, Irrigation, Irrigation systems, Irrigation practices, Infiltration.

The possibility of high frequency furrow irrigations is explored. Field data demonstrate the difficulty in evaluating infiltration parameters. Analyses of results indicate a number of advantages in high frequency furrow irrigations.

76:03F-110
IRRIGATION MANAGEMENT OF SHORT-SEASON, HIGH-DENSITY COTTON,
Mohammed, R.A. and Fangmeier, D.D.
Arizona University, Department of Soils, Water and Engineering, Tucson, Arizona.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 9 p, 4 tab, 17 ref.

Descriptors: Irrigation, Irrigation systems, Cotton, Soil moisture, Soil water, Crop production, Crop response, Nutrients, Fertilization, Nitrogen.

It was concluded that an available soil moisture depletion of 50 to 55% at irrigation will give the highest yields for short-season, high-density cotton. This is compared to about 65% for conventional cotton. Changing the scheduling criteria during the season tended to reduce yields. Application of 100 pounds of

N per acre appears adequate for the soils studied. This provided adequate nitrogen for plant growth but did not result in high petiole nitrate values late in the season. For highest yields irrigation termination should be based on observations of boll load and maturity. Later irrigations tend to delay boll opening while terminating too early reduces yields and fiber quality. Careful monitoring of soil moisture and plant condition is both necessary and satisfactory for irrigation scheduling. With experience, feel and appearance of soil moisture condition was quite adequate for irrigation scheduling. Other methods were more expensive and time consuming but were no better than field observations. Yields were comparable to those obtained with conventional cotton for the years studied. Water requirements were similar to those for conventional cotton. Early termination reduced the number of irrigations by one and in 1974 reduced the yield by 17%.

76:03F-111
THE DEVELOPMENT OF A FURROW-MULCH RIDGER,
Richey, C.B. and Griffith, D.R.
Purdue University, Department of Agricultural Engineering, Lafayette, Indiana
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 18 p, 7 fig., 3 tab, 16 ref.

Descriptors: Furrow irrigation, Surface irrigation, Erosion, Erosion control, Furrows, Flow resistance, Flow, Soybeans.

A tillage tool to form ridges for row crops but leave residue on the surface in the furrows has been developed. It gives promise of combining early plant growth and weed control approaching plowing with moisture conservation and erosion control approaching the no-till system.

76:03F-112
BUDGET FOR YOUR NITROGEN IDEAL SUGARBEETS,
Westfall, D.G.
The Great Western Sugar Company, Agricultural Research Center, Longmont, Colorado
Crops and Soils Magazine, Vol. 28, No. 5, p 12-14, February 1976. 3 fig.

Descriptors: Nitrogen, Nutrients, Fertilizers, Fertilization, Sugarbeets, Crop production, Agriculture.

This budget technique is a foolproof way of determining the fertilizer recommendation for sugarbeets that is a vital link in efficient production. By using this technique, you no longer have to apply nitrogen fertilizer blindly. You have a technique that has proven itself by reaching the compromise of optimum yield of high sugar content sugarbeets.

76:03F-113
BAND APPLICATION: A BETTER LESS COSTLY WAY TO FERTILIZE YOUR CROPS,
Richards, G.E.
Olin Corporation, Northern Regional Agronomy
Crops and Soils Magazine, Vol. 28, No. 9, p 10-11, August/September 1976

Descriptors: Fertilizers, Fertilization, Nutrients, Crop production, Agriculture.

Band application of phosphatic fertilizer or a combination of band plus broadcast is the most efficient and most profitable way to apply fertilizer over both the long or short term. Band application of phosphorus takes less fertilizer. Banding reduces fertilizer costs, interest costs, and application costs. It may also reduce fuel costs. Banding extends planting time by only 30 seconds per acre.

76:03F-114
NEW ROW CROP DRIP IRRIGATION USE,
Hall, B.J.
California University, San Diego, California
Drip/Trickle Irrigation, Vol. 1, No. 1, p 26-27, June 1976. 5 fig.

Descriptors: Irrigation, Irrigation practices, Irrigation systems, Crop production, Irrigation efficiency.

The increase of drip irrigation over furrow application for row crops was substantial last year, and it will make real inroads in 1976. Drip irrigation is expanding rapidly in crops of staked tomatoes, strawberries, cucumbers, squash, peppers, and soft squash. In San Diego County, tomatoes were irrigated last year with several drip irrigation systems, and this year two to three thousand acres will be in drip irrigation. Over 50 percent of the strawberry plantings in California are in drip irrigation. The use of drip irrigation will expand into new lower gross income crops for water savings and other benefits.

76:03F-115
FERTILIZER AND CHEMICAL INJECTION,
Schnedl, D.
Dymax Group
Drip/Trickle Irrigation, Vol. 1, No. 3, p 23-25, October 1976.

Descriptors: Fertilizers, Fertilization, Nutrients, Irrigation, Irrigation practices, Irrigation water.

The methods in general use for fertilizer and chemical feeding, in order of increasing preference, are: 1) Simple metering into the irrigation water, 2) Use of a venturi/bypass system, 3) A metering pump, 4) Proportionate feeding, using a pump, pulse-generating flow meter and counter/timer control unit, and 5) Proportionate feeding using a pump, flow meter with pulsed output and an SCR/variable speed DC drive. The discussion applies to fertilizers, herbicides, algaecides, chlorine and other chemicals.

76:03F-116
NITROGEN NOW AND TOMORROW,
Parker, J.H.
Tennessee Valley Authority, National Fertilizer Development Center, Tennessee
Crops and Soils Magazine, Vol. 28, No. 8, p 12-14, June-July 1976.

Descriptors: Nitrogen, Fertilizers, Fertilization, Nutrients.

We can expect to continue to have nitrogen fertilizers in the future. The dominance of natural gas as a feedstock for ammonia production will diminish, being supplemented by coal late in this century. Further in the future, processes based on nuclear electricity and/or heat may become dominant. Other approaches that now appear exotic could assume significance if researchers are able to manipulate nature's secrets successfully. But we still face the possibility of short-term scarcities when we have fast-changing market conditions.

76:03F-117
ONE DROP AT A TIME,
Flaherty, D.
Quest, Vol. 12, No. 4, p 4-9, Winter-Spring 1976. 8 fig.

Descriptors: Irrigation, Irrigation systems, Irrigation practices, Irrigation water, Filters, Filtration.

With multiple demands increasing for a finite supply of water, the drip system of irrigation has a lot more to offer, once some problems are solved. Engineers and Scientists at Washington State University are working on the problems.

76:03F-118
SUBTERRANEAN IRRIGATION,
Morey, D.
Irrigation Journal, Vol. 26, No. 1, p 16-18, January-February 1976. 4 fig.

Descriptors: Irrigation, Irrigation practices, Subsurface irrigation, Turf, Turf grasses, Irrigation efficiency.

The PAT System involves the scientific construction of playing surfaces of natural turf and soil over a perscribed mixture of sand to a depth of 16 to 24 inches. Then a network of plastic pipe, with slits at uniform intervals, connected to suction pumps controls the water flow (either off the field or onto the root zone for irrigation). Electric heating cables can also be provided which will extend the frost-free season and lengthen the turf growing season. Underneath all this is the plastic sheeting which creates the barrier against underground water rising to the playing surface. Presently this is a special ten-mil thick vinyl sheeting welded together in massive sheets which are gate folded before movement from the factory to the construction site. Properly engineered and technically constructed, the PAT System promises to offer the answer to the many faults of artificial turf and to provide a fine natural turf playing surface for an extended season that can take a real beating without showing the damage of athletic fields of yesterday.

76:03F-119
WEED MANAGEMENT TOOL HERBIGATION FOR IRRIGATED CROPLAND,
Siefert, W.
Nebraska University, Lincoln, Nebraska
Crops and Soils Magazine, Vol. 28, No. 5, p 10-11, February 1976. 2 fig, 1 tab.

Descriptors: Herbicides, Crop production, Irrigation, Irrigation practices, Irrigation systems, Irrigation water.

If you irrigate, you have a good alternative to conventional ground or air chemical applications for weed control. The alternative is herbigation--applying herbicides through the irrigation system. Herbigation has been researched for several years and is gaining acceptance among irrigators. Good results can be obtained with herbigation in any type of irrigation system.

76:03F-120
DRIP SYSTEM APPLIES PHOSPHORUS,
Irrigation Journal, Vol. 26, No. 1, p 24, January-February 1976.

Descriptors: Irrigation, Irrigation practices, Phosphorus, Nutrients, Fertilizers, Fertilization.

Results from recent University of California studies show that injection of phosphorus fertilizer through a drip irrigation system may be more feasible than commonly thought.

76:03F-121
REMOTE SENSING OF SOIL MOISTURE,
Irrigation Journal, Vol. 26, No. 5, p 30-31, September-October 1976. 3 fig.

Descriptors: Soil moisture, Soil water, Remote sensing, Irrigation, Temperature.

Like physicians taking the temperature and blood pressure of human patients, U.S. Department of Agriculture scientists are testing the temperature and blood, or sap pressure of plants, looking for clues that will indicate under what soil-moisture conditions the plants are growing.

76:03F-122
LOW-COST 'BUBBLER' IRRIGATION SYSTEM DEVELOPED,
Irrigation Journal, Vol. 26, No. 4, p 30, July-August 1976. 2 fig.

Descriptors: Irrigation, Irrigation systems, Irrigation efficiency, Water conservation.

A simply installed, low-cost, low-pressure nearly maintenance-free system of "bubbler" irrigation for tree crops is described.

76:03F-123
FEASIBILITY OF USING SOLAR ENERGY TO DRIVE IRRIGATION PUMPS,
Larson, D.L., Sands, C.D., II, Towle, C., Jr. and Fangemeier, D.D.
Arizona University, Department of Soils, Water and Engineering, Tucson, Arizona.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 18 p, 5 fig, 8 tab, 15 ref.

Descriptors: Irrigation, Irrigation practices, Solar radiation, Project planning, Irrigation engineering, Energy, Economics.

The technical and economic feasibility of using solar energy to drive irrigation pumps have been studied to determine the conditions required for serviceable, competitive use of solar systems. Solar power plant component development, changes in irrigation and pumping practices, investment incentives and higher fuel prices may all be required for economical use of solar energy.

76:03F-124
COMPUTERIZED IRRIGATION SCHEDULING METHOD MAY SAVE FARMERS MILLIONS OF DOLLARS,
Irrigation Journal, Vol. 12, No. 5, p 24-25, September-October 1976. 1 fig.

Descriptors: Irrigation, Irrigation practices, Water conservation, Computer programs.

A new computerized method of irrigation scheduling which could result in a 30 to 35 percent savings in the state's water and energy requirements for irrigation has been put on the Agriculture Computer Network (AGNET) by University of Nebraska-Lincoln agricultural engineers.

76:03F-125
LOW-COST 'BUBBLER' DEVELOPED,
Irrigation Age, Vol. 11, No. 1, p 20, September 1976.

Descriptors: Irrigation, Irrigation systems, Irrigation efficiency, Water conservation.

A simply installed, low-cost, low-pressure nearly maintenance-free system of "bubbler" irrigation for tree crops is described.

76:03F-126
SPOON-FEEDING NITROGEN,
Irrigation Age, Vol. 11, No. 1, p 18-19, September 1976. 3 fig.

Descriptors: Nitrogen, Nutrients, Fertilizers, Fertilization, Crop production.

Producing a bushel of corn with one pound of fertilizer requires accurate soil and water testing, skillful programming and a good understanding about nutrient uptake of the corn plant. That is why a Colorado farmer is concentrating on three areas which can help hedge against yield-depleting adversities: more efficient nutrient programming, better water scheduling and improved tillage techniques.

76:03F-127
DRIP/TRICKLE IRRIGATION GENERATING GROWTH, OPTIMISM,
Ross, R.
Irrigation Age, Vol. 11, No. 3, p 14-16, November-December 1976. 1 fig.

Descriptors: Irrigation, Irrigation practices, Irrigation systems, Water conservation, Irrigation efficiency.

Irrigation Age, in a series of personal interviews during the International Drip Irrigation Association meeting, spoke to several representatives of various drip/trickle industry segments.

76:03F-128
LOW-COST SAND AND GRAVEL SEPARATOR,
Humpherys, S.
Snake River Conservation Research Center, Kimberly, Idaho.
Irrigation Age, Vol. 11, No. 3, 1 p, November/December 1976. 2 fig.

Descriptors: Filtration, Irrigation, Sprinkler irrigation, Irrigation practices.

Many wells supplying sprinkler systems produce sand and small gravel in varying amounts and sizes. Sand and gravel particles lodge in the sprinkler nozzles and plug them. Anyone with such a well knows that continually unplugging nozzles can be exasperating. Also, plugged nozzles affect water distribution and sand in the water increases nozzle wear. Raymond Humpherys and his son, Jerry, who sprinkle irrigate their dairy farm in Star Valley, Wyoming, experienced this problem. To solve the problem, they purchased a 58-inch diameter, 442 gallon buoy tank from a military surplus disposal year for less than $100. They connected the buoy to the buried pipeline from their pump as shown in the drawing. The 10-inch inlet pipe was welded into the tank just below mid-height and close to one side. The outlet pipe was welded into the tank near the top. Water flowing through system creates circulation motion causes a centrifugal force which moves the heavier particles to the outside where the water velocity is lower. The particles then settle to the bottom and accumulate in the center.

76:03F-129
EVAPORATIVE COOLING OF PEACH TREES TO BREAK REST AND DELAY BLOOM,
Chesness, J.L., Hendershott, C.H., and Couvillon, G.A.
Georgia University, Department of Agricultural Engineering, Athens, Georgia.
Paper No. 76-2039, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976. Lincoln, Nebraska, 12 p, 2 fig, 3 tab, 10 ref.

Descriptors: Peaches, Orchards, Sprinkler irrigation, Evaporation, Irrigation systems, Irrigation effects, Irrigation practices.

The Utah Pheno-Climatography Model was used to predict rest completion and bloom dates for Loring Peach Trees. Individual tree sprinklers with an application rate of 0.086 per hour (0.218 cm/hr) were utilized over a 31-day period to achieve a 14-day bloom delay.

76:03F-130
OPERATING LARGE TRAVELING 'GUN' SPRINKLERS IN WINDS,
Shull, H. and Dylla, A.S.
United States Department of Agriculture, Agricultural Research Service, Morris, Minnesota 56267.
Paper No. 76-2014, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976, Lincoln, Nebraska. 5 tab, 8 ref.

Descriptors: Winds, Wind velocity, Irrigation efficiency, Uniformity, Irrigation systems, Sprinkler irrigation, Minnesota.

Studies of the wind distortion of water application patterns from large single-nozzle 'gun' irrigation sprinklers in west central Minnesota, where high winds are prevalent during the irrigation season, show that wind adversely affects the application pattern. When 'gun' sprinklers are used as traveling sprinklers, there is no acceptable travel lane spacing that will give a Cu value of 85% or greater under all of the wind conditions to be expected in windy areas. Acceptable water application uniformity can be achieved with wind velocities up to about 25% of the no wind wetted diameter for the sprinkler, an unacceptable solution. Limiting irrigation to periods when the wind velocity does not exceed about 3 m/sec, and the wind direction is normal to the travel lane direction, will usually produce a Cu value of 85% or more. In some areas average daytime winds exceed 4 m/sec (9 mi/hr) during the cropping season, however, wind velocity usually decreases at night. If night irrigation is possible it will provide a higher Cu value than daytime irrigation because of the reduced wind velocity. If an operator has a choice of travel land direction, the direction should be normal to the prevailing wind direction.

76:03F-131
AUTOMATION OF ON-FARM IRRIGATION TURNOUTS UTILIZING JACK-GATES,
Dedrick, A.E. and Erie, L.J.
United States Department of Agriculture, Agricultural Research Service, United States Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona 85040
Paper No. 76-2049, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 6 fig, 3 tab, 7 ref.

Descriptors: Basins, Irrigation, Irrigation systems, Irrigation efficiency, Irrigation practices, Automation, Flood irrigation, Surface irrigation.

A 26.3 ha (65-acre) field, divided into eight level basins that are independently irrigated from a centrally-located concrete-lined canal using single outlet jack-gates, has been automated with pneumatic controls and air cylinders. The system has been successfully operated for 14 irrigation cycles (May 1975 through May 1976). The last 12 irrigations were completed by the farmer and/or his irrigator without assistance from the developers/researchers.

76:03F-132
UNIFORMITY OF DISTRIBUTION IN UNDERTREE IRRIGATION IN ORCHARDS,
Karmeli, D. and Walker, W.R.
Technion - Israel Institute of Technology, Lowdermilk Faculty of Agricultural Engineering, Haifa, Israel.
Paper No. 76-2012, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 14 p, 3 fig, 2 tab, 6 ref.

Descriptors: Sprinkler irrigation, Irrigation efficiency, Irrigation systems, Irrigation, Uniformity, Orchards.

Sprinkler uniformity was evaluated in two citrus orchards using nozzles of varying angles. Results were analyzed using the Christiansen Uniformity Coefficient as well as the wetting zone technique. The effects of nozzle angle as well as foliage density were determined.

76:03F-133
MINIMUM ENERGY DESIGNS FOR SELECTED IRRIGATION SYSTEMS,
Chen, K.L., Wolfe, J.W., Wensink, R.B., and Kizer, M.A.
Oregon State University, Department of Agricultural Engineering, Corvallis, Oregon 97331
Paper No. 76-2037, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976, Lincoln, Nebraska, 7 fig, 5 tab, 6 ref.

Descriptors: Computers, Computer programs, Model studies, Simulation analysis, Irrigation, Irrigation systems, Irrigation efficiency, Energy, Model studies, Surface irrigation, Sprinkler irrigation.

A computer model has been developed which simulates the total energy requirement and determines the designs requiring minimum energy consumption for various irrigation systems. The model simulates each system by modularizing its energy needs into four basic areas: installation, operation, transportation, and manufacturing. The model considers the total, non-renewable energy resources used in the form of fossil fuel. Simulation model output determined the following relatively consistent energy utilization hierarchy among the irrigation systems. The effects of field size on minimum center pivot, permanent, and solid set systems. The effects of field size on minimum energy requirements for each irrigation system were relatively small but indicated that solid set and permanent designs should be based on small scale fields, that hand move and side roll designs reached minimum designs with 80-acre fields, and that drip and surface systems' energy requirements remained relatively constant as the field sizes were varied from 20 to 160 acres.

76:03F-134
A LOOK AT CROP YIELDS ALONG THE COLORADO IN 2000 AD,
Robinson, F.E.
California University, Department of Land, Air and Water Resources, Water Science and Engineering Section, Davis, California.
1976 Annual Technical Conference Proceedings, Sprinkler Irrigation Association, Technology for a Changing World, February 22-24, 1976, Kansas City, Missouri, p 131-132. 13 ref.

Descriptors: Technology, Irrigation, Crop production, Colorado River, Sprinkler irrigation, Irrigation efficiency.

Technology is advancing into the changing world and is propelled from many directions. This change could improve yields along the Colorado because of improved uniformity of the sprinkling and precision placement.

76:03F-135
MANAGEMENT FOR OPTIMUM EFFICIENCY,
Howell, T.A.
Texas A&M University, Department of Agricultural Engineering, College Station, Texas 77843.
1976 Annual Technical Conference Proceedings, Sprinkler Irrigation Association, Technology for a Changing World, February 22-24, 1976, Kansas City, Missouri, p 79-88. 1 fig, 7 tab, 7 ref.

Descriptors: Irrigation water, Irrigation efficiency, Agriculture, Crop production, Water quality, Optimization, Dynamic programming, Model studies.

The proper utilization of natural resources has never held a more prominent position in our society than in these present times. The influence and effects of water on the world food supply are extremely important. The irrigation water utilized in agriculture in the future will probably be much lower in quality and quantity than that found in present use. The proper management of these water supplies will become increasingly important. This paper will focus on using high frequency irrigation to maximize a crop yield with a limited quantity of irrigation water. The purpose was to utilize existing soil water and precipitation in conjunction with supplemental high frequency irrigation to increase crop yields. The specific objectives of this paper are to optimize the irrigation decisions under high frequency irrigation so that the maximum yield was obtained with a given quantity of irrigation water. Dynamic programming was used to optimize the multi-stage decision problem. System simulation was utilized to simulate the stochastic state transitions.

76:03F-136
DRIP IRRIGATION - WORLDWIDE 1975 PRESENT STATUS AND OUTLOOK FOR DRIP IRRIGATION,
Gustafson, C.D.
California University, San Diego, California
1976 Annual Technical Conference Proceedings, Sprinkler Irrigation Association, Technology for a Changing World, February 22-24, 1976, Kansas City, Missouri, p 58-65.

Descriptors: Irrigation, Irrigation systems, Irrigation efficiency, Irrigation practices, Orchards, Crop production.

The 1975 Worldwide Drip (Trickle) Irrigation Survey is the second such survey. The first one in 1974 provided the first real look at what was happening to drip irrigation in the United States and throughout the world. It is now over six years since drip irrigation was introduced into California to be used on commercial agricultural crops. The initial work began on an experimental five-acre avocado orchard in northern San Diego County. Experimentation has spread to many countries of the world and to most of the United States. Large scale plantings, utilizing drip irrigation, of most agricultural crops, have gone in. In July, 1974, the 2nd International Drip (Trickle) Irrigation Congress was held in San Diego, California. It was the culmination of five years of research, field testing and growers using the new method of irrigation. Twenty-nine countries were represented at the week long meetings, and with delegates from almost all the states of the U.S.A. in attendance. Over 100 technical papers were presented and are contained in the Proceedings of the Congress. Sixty-five manufacturers displayed their products in seventy booths. Opening day for the exhibits drew 2,000 people. One thousand persons registered for the Congress with each scientific session drawing 800-900 growers, scientists, commercial company representatives and educators.

76:03F-137
SPRINKLER UNIFORMITY MEASURES AND SKEWNESS,
Chaudhry, F.H.
Excola de Engenharia de Sao Carlos, Deparamento de Hidraulica e Saneamento, Sao Carlos (SP), Brasil
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR4, p 425-433, December 1976. 3 fig, 14 ref.

Descriptors: Sprinkler irrigation, Irrigation efficiency, Irrigation systems, Irrigation design, Infiltration.

The relationships between the more popular measures of uniformity of sprinkler irrigation have been studied both theoretically and experimentally taking into account the skewness of the precipitation distribution. The theoretical results show reasonable agreement with the data. Excellent agreement in the case of pattern efficiency leads to the conclusion that the smaller precipitations are well described by the assumed gamma distribution. The effect of skewness, in general, is to increase the pattern efficiency and the coefficient of Christiansen. The linear relationships that exist between these parameters are conditioned by the extent of skewness. This study shows that the conversion of one parameter into another which is sometimes practiced in the design of sprinkler systems may be risky if the skewness is disregarded.

76:03F-138
IRRIGATION TAILWATER LOSS AND UTILIZATION EQUATIONS,
Schneider, A.D.
United States Department of Agriculture Southwestern Great Plains Research Center, Agricultural Engineering, Bushland, Texas.
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR3, p 461-464, December 1976. 2 fig, 4 ref.

Descriptors: Tailwater, Irrigation, Furrow irrigation, Surface irrigation, Irrigation systems, Return flow, Irrigation efficiency, Irrigation water.

Allowing irrigation tailwater runoff is the commonly accepted practice for fully irrigating the lower end of graded furrows or borders. Irrigation-system water losses are minimized by proper balance between tailwater losses and deep percolation losses. Criddle et al. (3) recommended an irrigation advance time equal to one-fourth of the application time. To reduce tailwater losses, they recommended a 'cutback' furrow stream during the latter part of the irrigation set. Irrigation tailwater recovery systems can reduce the water losses that occur without a cutback furrow stream. Bondurant (2) presented design criteria for tailwater recovery systems and recommended operating the systems to achieve a reduced furrow stream input. A knowledge of the relative importance of design variables and the ability to place bounds on tailwater loss and recovery aids the engineer with limited design information. This paper develops equations that show the relative importance of the variables affecting tailwater loss and utilization.

76:03F-139
EFFECTS OF IRRIGATION SCHEDULING AND COORDINATED DELIVERY ON IRRIGATION AND DRAINAGE SYSTEMS,
Gear, R.D., Dransfield, A.S., and Campbell, M.D.
United States Department of the Interior, Bureau of Reclamation, Lower Colorado Region.
Presented at the National Water Resources and Ocean Engineering Convention of the American Society of Civil Engineers, April 5-8, 1976, San Diego, California, 17 p, 3 fig, 3 ref.

Descriptors: Scheduling, Irrigation, Irrigation practices, Neutron absorption, Crop production, Soil moisture, Soil water, Irrigation efficiency.

A simple, accurate technique has been worked out to schedule irrigations, using a graphic display of neutron probe measurements. The neutron probe design has been changed to combine the scaler with the shield and provide a useful field tool from what has traditionally been used almost exclusively for research. The technique used for scheduling irrigation requires only the identification of the refill point for each field and the neutron measured water content with time. Evidence collected from 40 fields with 7 crops during the summer of 1975 shows inconsistent irrigation timing with respect to available moisture. Consistent timing alone could improve water use efficiency by more than 10 percent. The neutron probe measurements of soil moisture depletion yield values of transient water use by plants as well as transient water loss by drainage. These two values together, divided by the water applied yield the efficiency for the field.

76:03F-140
DEVELOPMENT AND EVALUATION OF EVAPOTRANSPIRATION MODELS FOR IRRIGATION SCHEDULING,
Wright, J.L., and Jensen, M.E.
United States Department of Agriculture, Agricultural Research Service, Snake River Conservation Research Center, Western Region, Kimberly, Idaho 83341
Paper No. 76-2063, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 11 p. 6 fig, 1 tab, 4 ref.

Descriptors: Evapotranspiration, Crop production, Irrigation, Micrometeorology, Idaho, Lysimeters, Soil water, Beans.

Evapotranspiration (ET) from irrigated crops as a function of crop, soil and micrometeorological conditions has been studied for several years in the arid region of southern Idaho. Earlier results were used to develop relationships for estimating net radiation and potential ET as used in the USDA-ARS Computerized Irrigation Scheduling Program. Estimates obtained with the earlier relationships are compared with recent measurements obtained with two sensitive weighing lysimeters. Procedures used in the development of crop curve relationships are presented for some of the crops studied to date. The performance of the scheduling program in predicting the depletion of soil water for two years of irrigated beans are presented to demonstrate the accuracy of the procedures. The importance of obtaining representative meteorological data for irrigation scheduling is discussed.

76:03F-141
THE ROLE OF SIMULATION MODELS IN IRRIGATION SCHEDULING,
Jensen, M.E., and Wright, J.L.
United States Department of Agriculture, Agricultural Research Service, Snake River Conservation Research Center, Western Region, Kimberly, Idaho 83341.
Paper No. 76-2061, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 14 p. 4 fig, 2 tab, 25 ref.

Descriptors: Simulation analysis, Model studies, Scheduling, Climatic data, Crop production, Irrigation, Irrigation systems, Evapotranspiration, Colorado, California, Idaho, Irrigation efficiency.

The role of simulation models in irrigation scheduling based on daily climatic data is discussed. Simulation models provide tools that are valuable in the hands of trained and experienced irrigation specialists. Also, simulation models are needed by service groups to provide irrigation scheduling services at a reasonable cost. A summary of factors affecting confidence levels in irrigation scheduling is presented along with approximate magnitudes of the standard deviations to be expected for each. Generally the error associated with the amount of irrigation water applied exceeds the error due to ET estimates until the field can be monitored.

76:03F-142
EVAPOTRANSPIRATION POTENTIAL UNDER TRICKLE IRRIGATION,
Walker, W.R., Smith, S.W., and Geohring, L.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado 80523.
Paper No. 76-2009, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 22 p. 7 fig, 18 ref.

Descriptors: Evapotranspiration, Irrigation, Irrigation systems, Scheduling, Irrigation efficiency, Lysimeters, Peaches, Orchards, Soil moisture.

Predicting evapotranspiration under trickle irrigated systems has posed difficult problems in scheduling and design because of the lack of generally applicable information. A review of currently available mythodology is given along with lysimeter studies to assess the state-of-the-art. Application of findings is made to a young peach orchard which is trickle irrigated by soil moisture sensors.

76:03F-143
MANAGING SALINE WATER FOR IRRIGATION,
Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Lubbock, Texas.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976. 618 p.
(see 76:05C-002)

SECTION XIX

WATER QUANTITY MANAGEMENT AND CONTROL

CONTROL OF WATER ON THE SURFACE (GROUP 04A)

76:04A-001
MANNING'S ROUGHNESS FOR ARTIFICIAL GRASSES,
Graf, , W.H., and Chhun, V.H.
Ecole Polytechnique Federale de Lausanne, Laboratoire d'Hydraulique, Switzerland.
Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 102, No. IR4, Proceedings Paper 12603, p 413-423, December 1976.
8 fig, 2 tab, 9 ref, 2 append.

Descriptors: *Grasses, *Channels, *Roughness (Hydraulic), Roughness coefficient, Reynolds number, Hydraulic properties, Hydraulics, Laboratory tests, Testing, Equations.

Roughness of three types of artificial grass was investigated. Artificial grass consists of a mattress that simulates the soil surface where groups of grass are fixed in longitudinal and radial rows. The experiments were conducted in rectangular and triangular laboratory flumes. The following conclusions can be drawn: The n-value was found to be dependent on the flow depth and on the Reynolds number at low range of depths. The n-value was shown to be independent of the flow parameters at a high range of depths. The constant roughness coefficient values for the higher discharges were n = 0.032, n = 0.027, and n = 0.020 for the different artificial grasses. These n-values are in good agreement with the experimental results for 'real' grass found in the literature. It may be concluded, therefore, that artificial grass will be a useful material when simulating grass in the hydraulic laboratory.

76:04A-002
FIELD AND LABORATORY EVALUATION OF BI-LEVEL DRAINAGE THEORY,
Chu, S.T., and DeBoer, D.W.
South Dakota State University, Department of Agricultural Engineering, Brookings, South Dakota.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3, p 478-481, May-June 1976. 5 fig, 6 tab, 9 ref.
(See 02G-076)

76:04A-003
A THEORY OF FLOW RESISTANCE FOR VEGETATED CHANNELS,
Thompson, G.T., and Roberson, J.A.
Washington State University, Department of Civil and Environmental Engineering, Pullman, Washington.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 288-293, March-April 1976. 5 fig, 12 ref.

Descriptors: *Model studies, *Channel flow, *Flow resistance, Mathematical models, Drag, Vegetation, Roughness (Hydraulic), Flow, Viscosity, Fluid mechanics, Fluid friction, Hydraulics.

A theory was developed to predict the flow resistance in vegetated open channels. The solution technique was based on an analytical method originally proposed by Roberson for smooth conduits roughened with discrete submerged roughness elements. Flow conditions may either partially or fully submerge the cylinders. Included in the analysis is a method to predict the effect of flexible vegetation on flow resistance. The model also predicts resistance effects of a smooth boundary or one roughened by dense concentrations of small elements such as soil particle aggregates. An initial comparison of flume measurements of resistance for small diameter cylinders was given. The analytical model provides, in addition to resistance factor, other flow parameters involved in analytical solutions of vegetated open channel flow.

76:04A-004
OPERATIONS MODELS FOR CENTRAL VALLEY PROJECT,
Becker, I., Yeh, W.W.-G., Fults, D., and Sparks, D.
California University, Department of Engineering Systems, Los Angeles, California.
Journal of the Water Water Resources Planning and Management Division, Proceedings paper No. 12062, Vol. 102, No. WR1, p 101-115, April 1976.
2 fig, 1 tab, 29 ref. OWRT C-5184 (No. 4208)(3).

Descriptors: *Water resources, *Multiple-purpose projects, *Decision making, *Hydro-electric power, *California, *Optimization, Mathematical models, Reservoirs, Planning, Management, Operations research, Algorithms, Water policy, Linear programming, Dynamic programming.

System optimizing procedures are being developed for on-line use in the operation of the Central Valley Project in California, a complex multiple objective water resource system. The project is subject to requirements and interagency agreements. A practical optimization method must address not only these requirements but also the continuing needs of day-to-day operation, and the necessity for interposing the project managers in monitoring and final decision roles. The basic technical diffulty with an optimizing algorithm for a complex water resource system is the dimensionality which can easily run into the tens of thousands of decision variables and constraints. The method being developed for the project provides the necessary decomposition and involves the project managers, assisted by an integrated group of multiple policies based on interconnected monthly, daily, and hourly models, using iterated linear programming-dynamic programming techniques.

76:04A-005
A PROCEDURE FOR ESTIMATING OFF-SITE SEDIMENT DAMAGE COSTS AND AN EMPIRICAL TEST,
Lee, M.T., and Guntermann, K.L.
Illinois State Water Survey, Urbana, Illinois.
Water Resources Bulletin, Vol. 12, No. 3, p 561-575, June 1976. 5 fig, 3 tab, 22 ref.

Descriptors: *Agricultural watersheds, *Damages, *Costs, *Estimating, *Erosion, *Reservoirs, Methodology, Equations, Recreation, Benefits, Flood damage, Drainage, Storage, *Illinois, *Sediments.

Research was conducted to develop a methodology for estimating agricultural off-site sediment damage costs and an empirical estimate of such damages for a watershed is included. The economics of off-site sediment damage costs are discussed as a theoretical basis for the procedures developed. A detailed methodology is described for estimating five different types of off-site sediment damages commonly associated with rural watersheds. The methodology is then applied to a central Illinois watershed and estimates of individual types of damage are made. The estimates are combined into an off-site sediment damage function for the watershed, and the usefulness of the damage function for analyzing off-site sediment damages and achieving a reduction in those costs is discussed.

76:04A-006
OPERATION OF A RESERVOIR COLLECTING WATER FROM A SMALL WATERSHED,
Buras, N., Diskin, M.H., and Zamir, S.
Technion-Israel Institute of Technology, Lowdermilk Faculty of Agricultural Engineering, Haifa, Israel.
Water Resources Research, Vol. 12, No. 5, p 866-872, October 1976. 5 fig, 6 tab, 3 ref.

Descriptors: *Reservoir operation, *Optimization, *Economic efficiency, Watersheds (Basins), Operations research, Synthetic hydrology, Storm runoff, Decision making, Irrigation, Reservoir storage, Pumping, Costs, Benefits, Equations, *Small watersheds.

Best operation policies, linear and nonlinear, were developed for a small reservoir in which storm runoff water might be augmented by pumping water from another source. These policies were aimed at a full reservoir at the beginning of the yearly irrigation season and, indirectly, utilized more efficiently the existing neighboring pumping installations, which are usually idle in winter. The operating policies are expressed as time-dependent functions indicating the level of the reservoir which would ensure its being full at the end of the rainy season with a given probability. When these policies were tested with a synthetic hydrologic series of 45 years, it appeared that the cost of operating the reservoir was inversely proportional to the daily amount of water pumped into it from external sources.

76:04A-007
WIND EFFECTS ON WATER APPLICATION PATTERNS FROM A LARGE, SINGLE NOZZLE SPRINKLER,
Schull, H., and Dylla, A.S.
United States Department of Agriculture, North Central Region, North Central Soil Conservation Research Center, Morris, Minnesota.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 501-504, Special Edition 1976. 4 tab, 7 ref.

Descriptors: *Sprinkling, *Sprinkler irrigation, Winds, Uniformity coefficient, Irrigation, Irrigation practices, Irrigation effects, Irrigation systems.

This report describes a study to determine the effects of wind on the water application pattern for a stationary, single nozzle, gun type irrigation sprinkler. The effects of wind on application uniformity were determined by comparison of the wind-affected application patterns with calculated no-wind patterns. Deviation of the measured patterns from the no-wind patterns increased as wind velocity increased. Stationary application patterns were used to calculate the water distribution if the same sprinkler were traveling down lanes in a field. The calculated distributions from a traveling sprinkler were then overlapped with different travel lane spacings, and the Christiansen coefficient of uniformity value determined for each spacing. A regression equation was developed to give maximum travel lane spacing to obtain a coefficient of uniformity value of 0.85 as a function of wind conditions and water pressures. Both wind velocity and water pressure at the sprinkler elbow influence the water distribution. Also, for a traveling gun, wind direction relative to travel direction provides an additional affect; as the wind direction more nearly approaches the travel direction, lane spacing must be decreased to maintain acceptable application uniformity.

76:04A-008
SIMULATING OVERLAND FLOW IN BORDER IRRIGATION,
Bassett, D.L., and Fitzsimmons, D.W.
Washington State University, Department of Agricultural Engineering, Pullman, Washington.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 666-671, Special Edition 1976. 3 fig, 2 tab, 15 ref.

Descriptors: *Border irrigation, *Surface irrigation, *Overland flow, Simulation analysis, Mathematical models, Model studies, Irrigation, Irrigation systems.

A mathematical model of the border irrigation process is introduced. It is based on the complete equations of continuity and momentum for unsteady, spatially varied flow in open channels. The equations are solved approximately by the method of characteristics. Simulated irrigation are compared to test data. Agreement between simulated and observed data is generally satisfactory. Applications of the model are suggested.

76:04A-009
SURFACE MODIFICATIONS FOR WATER MANAGEMENT AND SALINITY CONTROL IN A NONIRRIGATED AREA,
Rektorik, R.J., Allen, R.R., and Lyles, L.
Agricultural Research Service, United States Department of Agriculture, Department of Agricultural Engineering, Weslaco, Texas.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 699-703, Special Edition 1976. 6 fig, 2 tab, 15 ref.

Descriptors: Saline soil, Salinity, Leaching, Runoff, Surface runoff, Grain sorghum, Cotton, Crop production, Salt.

Leveling the saline soil areas in a field to a plane 9 cm lower than that of the nonsaline soil areas allows water from high intensity rains to run off from the higher nonsaline soils and pond on the saline soils, thus providing leaching water. Original soil salinity for the 0-90 cm soil profile was reduced 53 to 16 percent in the saline and nonsaline areas, respectively. Grain sorghum (1969) and cotton (1970) yields were 47 and 38 percent greater than yields from an adjacent untreated field.

76:04A-010
ESTIMATING SEEPAGE LOSSES FROM CANAL SYSTEMS,
Worstell, R.V.
Snake River Conservation Research Center, Department of Agricultural Engineering, Kimberly, Idaho
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR1, p 137-147, March 1976. 5 fig, 3 tab, 22 ref.

Descriptors: Seepage, Canal seepage, Irrigation districts, Irrigation, Canals.

Seepage and operational losses from distribution systems are continuing problems for designers and managers of irrigation districts and for water users. The designer must provide sufficient capacity in the canals to allow for these losses, and the managers must divert extra water into parts of the system to assure ample flow to the lower reaches of all laterals. The water users must provide for ample storage to offset problems that arise if seepage losses cause high water tables in fields adjacent to the canal. As demands increase on all the water supplies of the West, regional and state resource management agencies are looking critically at the large volumes of water diverted by agriculture, especially when these volumes are much larger than the amounts used in evapotranspiration. These agencies need guidelines for more accurately determining reasonable water diversions to irrigated agriculture. A simplified method that engineers and resource planners can use to estimate seepage losses from new or existing canal systems is presented.

76:04A-011
LEAST COST IRRIGATION SYSTEM SPECIFICATIONS FOR VARIOUS CONDITIONS,
Busch, J.R.
Idaho University, Department of Agricultural Engineering, Moscow, Idaho.
Paper No. 76-2038, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976, Lincoln, Nebraska, 3 fig, 7 tab, 4 ref.

Descriptors: Model studies, Simulation analysis, Optimization, Irrigation systems, Economics, Irrigation efficiency, Water costs.

A methodology employing a dynamic-linear programming model was used to develop optimum rehabilitation plans for an irrigation district. The plans developed indicate the total irrigation system cost and configuration for various levels of efficiency and water cost.

76:04A-012
CRITICAL IRRIGATION MANAGEMENT DECISIONS,
Corey, F.C.
Agricultural Technology Company, McCook, Nebraska.
1976 Annual Technical Conference Proceedings, Sprinkler Irrigation Association, Technology for a Changing World, February 22-24, 1976, Kansas City, Missouri, p 146-162. 3 fig, 5 ref.

Descriptors: Sprinkler irrigation, Irrigation, Furrow irrigation, Flood irrigation, Irrigation systems, Irrigation practices, Crop production, Irrigation efficiency.

With increasing land development and the millions of acreage already under sprinkler and gravity irrigation it is to the farmers interest (economically) to have a good engineered irrigation system and see that it is managed and operated in the most efficient manner to obtain maximum yields at the least cost. This irrigation system includes planning, development, maintenance and management of the well, the pumping system, and the sprinkler or distribution system. This paper will be limited to sprinkler irrigation and pertain to: (a) brief introduction to Ag Technology Co, (b) agricultural production, design and management problems observed by this company over the last five to ten years, (c) irrigation management techniques necessary to make critical irrigation decisions, and (d) any possible future trends and techniques necessary to management of our resources at an optimum level.

76:04A-013
OPERATION AND MAINTENANCE OF IRRIGATION AND DRAINAGE SYSTEMS: SECTION IV.---MAINTENANCE,
The Committee of Operation and Maintenance of Irrigation and Drainage Systems of the Irrigation and Drainage Division,
American Society of Civil Engineers,
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR1, p 1-107, March 1976. 30 fig, 3 tab, 43 ref.

Descriptors: Irrigation operation and maintenance, Irrigation, Irrigation canals, Irrigation ditches, Irrigation effects, Irrigation systems, Drainage effects, Drainage practices, Drainage systems, Drains, Salinity.

The subject of maintenance is treated in this manual by a discussion of the factors essential to keeping the facilities of an irrigation and drainage system in good condition, the staff necessary to accomplish the work and that staff's responsibility, and common practices and procedures used for the maintenance of structures and facilities pertinent to such systems. The irrigation systems referred to in this section, are those generally associated with the movement of water from its source to the user and which are prevalent in arid and semi-arid areas. The drainage systems are those in which seasonal removal of water is normally a necessity, due to possible water-logging of the soil, or the buildup of salts in it. The system involved may be an essential part of an irrigation system in an arid or semi-arid area or one of the larger and more extensive systems located in the semi-humid or humid areas.

76:04A-014
AUTOMATION OF AN OPEN-DITCH IRRIGATION CONVEYANCE SYSTEM UTILIZING TILE OUTLETS,
Erie, L. J., and Dedrick, A.R.
United States Department of Agriculture, Agricultural Research Service, United States Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona 85040
Paper No. 76-2050, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska, 14 p. 5 fig, 5 ref.

Descriptors: Irrigation, Irrigation practices, Irrigation systems, Automation, Basins.

An irrigation system on a 28.4 ha (70 acre) field divided into seven dead-level basins, irrigated from a centrally-located concrete-lined canal, using modified cylinders on jack-gates and structures utilizing air pillows or bellows, was automated by use of pneumatic controls. A structure was designed that would contain items pertinent to automation, so that turning the water into the field and shutting it off would be automatically accomplished according to a predetermined time schedule.

SECTION XX

WATER QUANTITY MANAGEMENT AND CONTROL

GROUNDWATER MANAGEMENT (GROUP 04B)

76:04B-001
AQUIFER MANAGEMENT UNDER TRANSIENT AND STEADY-STATE CONDITIONS,
Alley, W.M., Aguado, E., and Remson, I.
Stanford University, Department of Applied Earth Sciences, California.
Water Resources Bulletin, Vol. 12, No. 5, p 963-972, October 1976. 4 fig, 1 tab, 7 ref.

Descriptors: *Aquifers, *Management, *Groundwater, *Linear programming, *Optimization, Wells, Distribution, Pumping, Decision making, Methodology, Constraints, Mathematical models, Equations, Systems analysis.

The equations of transient and steady-state flow in two-dimensional artesian aquifers are approximated using finite differences. The resulting linear difference equations, combined with other linear physical and management constraints and a linear objective function, comprise a linear programming (LP) formulation. Solutions to such LP models are used to determine optimal well distributions and pumping rates to meet given management objectives for a hypothetical transient problem for a steady-state field problem.

76:04B-002
DRAWDOWN DUE TO PUMPING IN AN ANISOTROPIC AQUIFER,
Glover, R.E., and Moody, W.T.
Colorado State University, Department of Civil Engineering, Fort Collins, Colorado.
Water Resources Bulletin of the American Water Resources Association, Vol. 12, No. 5, p 941-950, October 1976. 3 ref, 1 append.

Descriptors: *Water wells, *Aquifers, *Drawdown, *Pumping, Permeability, Artesian wells.

Formulas for water table or pressure drawdowns due to wells drawing water from isotropic aquifers can be modified for use where the aquifer is nonisotropic. The cases treated are those for a well drawing water from an aquifer at a constant rate, for a well drawing water at a constant rate from an aquifer with a 'leaky roof', and for the flowing artesian well. In all cases the well is considered to completely penetrate the aquifer. The resulting cones of depression formed from pumping an anisotropic aquifer has an oval shape. The length of the major and minor axes of a contour of the cone of depression exhibit the ratio Kx/Ky with Kx the direction of maximum permeabiltiy, and Ky in the direction ofminimum permeability, which lies at right angles to Kx.

76:04B-003
A SIMULATION MODEL FOR OPERATING A MULTIPURPOSE MULTIRESERVOIR SYSTEM,
Sigvaldason, O.T.
Acres Consulting Services Limited, Niagara Falls, Ontario, Canada.
Water Resources Research, Vol. 12, No. 2, p 263-278, April 1976. 8 fig, 3 tab, 40 ref.

Descriptors: *Multiple-purpose reservoirs, *Reservoir operation,*Simulation analysis, *Optimum development plans, Water policy, Assessment, River basins, Reservoir storage, Networks, Equations, Mathematical models, Systems analysis, *Canada.

Described is a simulation model used for assessing alternative operating policies for the Trent River system in Ontario, Canada. The Trent basin has numerous reservoirs (48 were represented in the model). The reservoir system is used for flood control, water supply, hydropower, and augmenting flows through the canal system during the summer period. The need for assessing alternative policies arose from growing conflicts in recent years over satisfying all of the many water-based needs of the basin. The simulation model aided in assessing the impact of alternative policies. Every reservoir was subdivided into five storage zones (variable temporally). A time-based rule curve was prescribed to represent ideal reservoir operation. Ranges were prescribed for channel flows, which were dependent on water-based needs. The underlying concept of the model was the mathematical representation of the chief operator's perception of "optimum" operation and the derivation of this solution using a nested optimization submodel. "Penalty coefficients" were assigned to those varables which represented deviations from ideal conditions. Different operational policies were simulated by representing the entire reservoir system in "capacitated network" form and deriving optimum solutions for individual time periods with the "out-of-kilter" algorithm. The algorithm was computationally efficient, simplified model development, and permitted flexibility in readily using the model for a wide range of reservoir configurations and operating policies.

76:04B-004
FIELD DRAINAGE WITH MANIFOLD WELL POINTS,
Rektorik, R.J.
Agricultural Research Service, Weslaco, Texas.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 81-84, January-February 1976. 2 fig, 4 tab, 6 ref.
(See 76:05G-009)

76:04B-005
COST FUNCTIONS FOR ADDITIONAL GROUND WATER DEVELOPMENT,
Maddock, T. III.
Geological Survey, Water Resources Division, Reston, Virginia.
Water Resources Bulletin, Vol. 12, No. 3, p 539-545, June 1976. 2 tab, 9 equ, 6 ref.

Descriptors: *Groundwater, *Water resources development, *Water rights, Costs, Energy, Industries, Equations, Operating costs.

In many regions of the United States, the development of new water-intensive industries for production of energy may upset the existing water rights structure. Such an industry is coal gasification. This paper develops external cost functions for determining compensation to esisting groundwater users when additional withdrawals are requested by new users. The functions reflect increased energy costs, and as presented, they are based on a linear relation between drawdown and pumping. It is assumed that the fixed cost of drilling and completing wells and the variable cost of operating wells overshadow the pipeline company's compensatory payments. It is also assumed that the energy costs represent the profit losses to the original users. In conclusion, it should be noted that compensation payment will result in costs to new users that are not trivial.

76:04B-006
MODEL-FREE STATISTICAL METHODS FOR WATER TABLE PREDICTION,
Yakowitz, S.
Arizona University, Department of Systems and Industrial Engineering, Tucson, Arizona.
Water Resources Research, Vol. 12, No. 5, p 836-844, October 1976. 14 fig, 20 ref. NSF GK-35915, GF-38183.

Descriptors: *Water table, *Statistical models, *Depth, *Well data, *Arizona, Water wells, Time series analysis, Stochastic processes, Statistical methods, Homogeneity, Forecasting, Equations, Regression analysis, Water levels, Aquifer characteristics.

In this study a new approach for predicting future values of well depths on the basis of regional water table records was presented. Basically, well water level depths are viewed as random sequences, and the assumption is made that the region to be analyzed can be partitioned into several subregions of unknown geographic shapes which are statistically homogeneous in the sense that the record of each well in a fixed subregion is a different realization of the same stochastic process. Methods from clustering and time series analysis were used to find (1) the subregions of stochastic homogeneity, and (2) the statistical law for the same series of the wells in a given subregion. Forecasts were made and confidence bands constructed by using the methods espoused here (in conjunction with regression techniques) on Tucson basin data. The forecasts were compared to depths actually observed, and, for many wells, the agreement was sufficient to make these new methods appear promising.

76:04B-007
PUMPING-TEST ANALYSIS USING A DISCRETE TIME-DISCRETE SPACE NUMERICAL METHOD,
Rushton, K.R., and Booth, S.J.
Birmingham University, Department of Civil Engineering, (England).
Journal of Hydrology, Vol. 28, No. 1, p 13-27, January 1976. 11 fig, 3 tab, 10 ref.

Descriptors: *Groundwater, *Pumping, *Numerical analysis, *Aquifer characteristics, Wells, Computer models, Drawdown, Aquifer testing, Sand aquifers, Head loss, Resistance networks, Unsteady flow, Computers, Water wells, Turbulence.

The application of a digital computer model of radial flow in an aquifer to the estimation of aquifer parameters was considered. Pumping-test data for a shallow unconfined gravel aquifer, in which the drawdown recorded at the pumped well is a significant proportion of the thickness of the aquifer, were used to test the method. The model was sufficiently flexible to allow for decrease in the saturated thickness, vertical components of flow, well losses and variations of aquifer parameters in time and space.

76:04B-008
PUMPING TEST ANALYSIS WHEN PARAMETERS VARY WITH DEPTH,
Rushton, K.R., and Chan, Y.K.
Birmingham University, Department of Civil Engineering, (England).
Ground Water, Vol. 14, No. 2, p 82-87, March-April 1976. 5 fig, 4 ref.

Descriptors: *Aquifer testing, *Data processing, *Depth, *Numerical analysis, Computer models, Permeability, Storage coefficient, Aquifer characteristics, Test wells, Limestones, Fissures (Geologic), Fracture permeability, Pumping, Drawdown, Observation wells.

The analysis of pumping tests for the same borehole but with different rest water levels may lead to significantly different values of aquifer parameters. A numerical method of pumping-test analysis was introduced in which the permeability and storage coefficient can take different values depending on the current saturated depth. By introducing varying values of permeability and storage coefficient, the numerical model was used to represent pumping tests in a soft limestone aquifer.

76:04B-009
SHALLOW AQUIFERS RELATIVE TO SURFACE WATER, LOWER NORTH PLATTE RIVER VALLEY, WYOMING,
Herrmann, R.
United States Department of the Interior, National Park Service, Southeast Region, Altanta, Georgia.
Water Resources Bulletin, Vol. 12, No. 2, p 371-380, April 1976. 6 fig, 1 tab, 5 ref.

Descriptors: Ground water, Wyoming, Aquifers, Irrigation, Irrigation effects, Pumping, Pumping plants, Model studies, Numerical analysis, Groundwater recharge, Water resource, Alluvial aquifer.

The occurrence of ground water in the lower North Platte Valley, Goshen County, Wyoming was studied to determine safe yield within the alluvial aquifer under varying discharge and recharge conditions. The alluvium of the North Platte is extensively developed for irrigation purposes and the effects of large-scale pumpage are of major concern. Actual withdrawals are estimated to be 46,000 acre-feet. Should pumping reach potentially higher levels an overdraft is expected. Effect of ground water withdrawals are established from projections of the flow regime within the alluvial aquifer. A time dependent, numerical model was employed to predict aquifer response to increased withdrawals. The results suggest that more efficient use of surface waters and/or increased use of ground water will reduce the annual subsurface return flow to the North Platte River and its tributaries by an amount equal to the reduced groundwater increment. Alternatives are available for management of the lower North Platte alluvial aquifer. The preferred course is to correlate surface and subsurface water rights, in light of convenience, economics, and best means of storage for maximum utilization of the single water resource.

76:04B-010
ECONOMIC ANALYSIS OF ALTERNATIVE GROUNDWATER WITHDRAWAL RATES IN CONJUNCTION WITH SURFACE WATER IRRIGATION,
Feldman, M., Whittlesey, N.K., and Butcher, W.R.
Washington State University, Pullman College of Agriculture.
Washington Water Research Center, Pullman, Report No. 27, September 1976. 126 p, 5 fig, 28 tab, 1 ref, append. OWRT B-051-WASH(2). 14-31-0001-3945.

Descriptors: Groundwater, *Withdrawal, *Conjunctive use, *Irrigation, Aquifers, *Economics, *Groundwater mining, *Input-output analysis, Water level.

Eastern Washington is experiencing rapid decline in groundwater levels due to irrigation pumping of the essentially fixes stock of groundwater. This study develops a conceptual framework for comparing economic factors of the present management policy to avoid exceeding a 10 foot per year decline in the static water level with alternative policies allowing greater decline rates or augmenting the water supply with surface water diverted from the Columbia River. A well cost model was developed to provide estimates of water costs for every potential well in the study area under alternative rates of water level decline. A computer model of the groundwater aquifer was utilized to provide estimates of the amount and location of the water that could be withdrawn from the aquifer while remaining within the limits of any management policy. An agricultural model (utilizing linear programming) calculated discounted net returns to agriculture, including nonirrigated agriculture, over a 50 year period. An input-output model was used to estimate the secondary economic impacts of additional irrigation development that could result from alternative management policies. Results showed that the actual depth from which water may be pumped depends heavily upon the rate of decline and the static water level. If water levels are relatively stable, water may be economically pumped from considerable depths. Rapid decline rates in the static water level will reduce the absolute depth at which water may be pumped economically. The results indicate that some economic gains would accure to irrigated farms and the local economy under policies which encourage more water use. However, the economic gains are proportionately much less than the changes in water use required to induce the economic gain.

76:04B-011
DESIGN OF GROUNDWATER LEVEL OBSERVATION-WELL PROGRAMS,
Heath, R.C.
Geological Survey, Water Resources Division, Raleigh, North Carolina.
Ground Water, Vol. 14, No. 2, p 71-77, March-April 1976. 4 fig, 2 tab.

Descriptors: *Observation wells, *Network design, Hydrologic data, Discharge measurement, Recharge, Measurement, Aquifers, Data collections, Water level fluctuations, Water wells, *Withdrawal, *Groundwater recharge.

Data obtained from observation-well programs are used to determine: (1) the effect of withdrawals on recharge and natural discharge conditions, (2) the hydraulic characteristics of groundwater systems, and (3) the extent and degree of confinement of aquifers. Wells in these programs can be divided into three networks: (1) a hydrologic network which includes wells needed to determine the extent of aquifers and changes in storage; (2) a water-management network which includes wells needed to determine the effect of withdrawals and hydraulic characteristics; and (3) a baseline network which includes wells needed to determine the response of groundwater systems to natural changes such as those related to climate.

SECTION XXI

WATER QUANTITY MANAGEMENT AND CONTROL

EFFECTS ON WATER OF MAN'S NONWATER ACTIVITIES (GROUP 04C)

76:04C-001
WATER YIELDS RESULTING FROM TREATMENTS ON THE WORKMAN CREEK EXPERIMENTAL WATERSHEDS IN CENTRAL ARIZONA,
Rich, L.R., and Gottfried, G.J.
Rocky Mountain Forest and Range Experiment Station, Temple, Arizona.
Water Resources Research, Vol. 12, No. 5, p 1053-1060, October 1976. 8 fig, 2 tab, 12 ref.

Descriptors: *Water yield improvement, *Watershed management, *Arizona, Water supply, Water yield, Hydrology, Streamflow, Sedimentation, *Forest watersheds, Burning, Lumbering, Grasses waterways, Pine trees, Surface runoff, Ponderosa pinetrees, Instrumentation, Coniferous forests.

The three Workman Creek watersheds were instrumented to determine the hydrology of mixed conifer forests and to determine the changes in streamflow and sedimentation as a result of manipulating the forest vegetation. A small riparian cut on North Fork did not increase water yield. A selection timber harvest, improvement cut, and fire which removed 45% of the basal area on South Fork increased water yields slightly. In contrast, converting 32.4 ha (80 acres) of moist forest site to grass significantly increased water yields on the 100.4 ha (248 acre) North Fork watershed. Water yields were increased even more after 40.5 ha (100 acres) of dry-site pine forest were converted to grass. An increase of 69 mm (2.70 inches), or 84%, of expected runoff resulted from the combined treatment. Clearing 83% of the South Fork watershed preparatory to planting ponderosa pine significantly increased water yields by 93 mm (3.67 inches), or by 111%.

SECTION XXII

WATER QUANTITY MANAGEMENT AND CONTROL

WATERSHED PROTECTION (GROUP 04D)

76:04D-001
LABORATORY TESTING OF WATER-REPELLENT SOIL TREATMENTS FOR WATER HARVESTING,
Fink, D.H.
Agricultural Research Service, Water Conservation Laboratory, Phoenix, Arizona.
Soil Science Society of America Journal, Vol. 40, No. 4, p 562-566, July-August 1976. 3 fig, 2 tab, 13 ref.

Descriptors: *Repellents, *Water harvesting, *Laboratory tests, *Soil treatment, Watersheds (Basins), Soils, Water conservation, Arid lands, Erosion, Weathering, Stabilization, Soil stabilization, Soil science.

Field testing of repellents for water harvesting is both slow and costly, often hindering the orderly, rapid progression of the technique. Laboratory tests were developed for rapidly evaluating the effectiveness of water-repellent treatments on soils. The effect of accelerated weathering from ultraviolet radiation, ozone, and freeze-thaw cycling on the retention of water repellency and on soil stability was studied. The effect on soil stability of prolonged hydration and water erosion was also considered. Using these laboratory tests, numerous soils, organic materials, and treatment techniques can be quickly evaluated so that field testing can be reserved for only the most promising. A small, representative laboratory study, reported here to illustrate the technique, showed that two repellents (a petroleum resin dust-suppressant oil and paraffin wax) when combined made soil generally more resistant to total weathering effects than did either repellent alone. The dust suppressant helped to stabilize the soil against damage by freeze-thaw cycling, while the wax protected it from degradation by ultraviolet radiation. These laboratory results compared favorably with observations form field plots treated with these two repellents.

76:04D-002
EFFICIENCY OF NITROGEN, CARBON, AND PHOSPHORUS RETENTION BY SMALL AGRICULTURAL RESERVOIRS,
Gill, A.C., McHenry, J.R., and Ritchie, J.C.
Agricultural Research Service, Sedimentation Laboratory, Oxford, Mississippi.
Journal of Environmental Qualiry, Vol. 5, No. 3, p 310-315, July-September 1976. 3 tab, 29 ref.
(See 76:02J-002)

76:04D-003
A COMPARISON OF MODELING AND STATISTICAL EVALUATION OF HYDROLOGIC CHANGE,
Langford, K.J., and McGuinness, J.L.
Melbourne and Metropolitan Board of Works, Australia.
Water Resources Research, Vol. 12, No. 6, p 1322-1324, December 1976. 1 fig, 12 ref.

Descriptors: *Forest management, *Watersheds (Basins), Hydrology, *Statistical models, *Model studies, Mathematical models, Reforestation, *Watershed management, Lumbering, Surface runoff, Water yield, Runoff, Vegetation effects.

The U.S. Department of Agriculture Hydrography Laboratory model of watershed hydrology is adapted for use on a research watershed where land use changed drastically as a result of reforestation and subsequent thinning. Eight years of measured runoff from a mature forest are used to estimate two of the model parameters; the remaining 39 are based on physical measurements. Model simulations properly evaluated both the magnitude and statistical significance of the hydrologic changes with much fewer data than were needed for standard statistical analyses.

76:04D-004
SOIL AND WATER CONSERVATION WITH WESTERN IOWA TILLAGE SYSTEMS,
Spomer, R.G., Piest, R.F., and Heinemann, H.G.
Agricultural Research Service, North Central Watershed Research Center, Council, Bluffs, Iowa.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 108-112, January-February 1976. 2 fig, 3 tab, 11 ref.

Descriptors: *Soil conservation, *Water conservation, *Erosion control, *Cultivation, *Farm management, *Iowa, Runoff, Precipitation (Atmospheric), Rainfall, Crops, Corn (Field), Grasses, Terracing, Erosion rates, Cultivated lands, Sheet erosion, Soil erosion, Watersheds(Basins), Agricultural watersheds, Agricultural runoff, Agriculture.

Excessive rates of surface runoff and erosion from the research watersheds at Treynor, Iowa, were measured during a 10-yr study of two contour-planted watersheds cropped to corn. Low erosion rates occurred at a similarly cropped level-terraced watershed and from a bromegrass watershed. These measurements showed that level terraces and bormegrass are exceptionally effective conservation practices. But level terraces with point rows and irregular fields complicate farming and decrease farm machinery efficiency, and grass is not considered one of the more profitable crops for western Iowa loess soils. Mulch-tilled corn was also examined to assess its effect on surface runoff and soil loss. On one watershed, mulch tillage was used with parallel terraces (double normal spacing). The terrace-impounded water was removed by an underground drainage system, installed in the spring of 1972. The contour-planted watersheds lost more soil than the mulch-tilled, parallel-terraced watershed in 1972.

76:04D-005
CURRENT METHODS USED IN THE SOIL CONSERVATION SERVICE TO ESTIMATE SEDIMENT YIELD,
Nicholas, E.C.
Soil Conservation Service, Fort Worth, Texas.
Paper No. 76-2532, American Society of Agricultural Engineers 1976 Winter Meeting, Chicago, Illinois, 8 p, December 14-17, 1976. 2 fig, 7 ref.

Descriptors: *Sediment yield, *Sedimentation rates, *Soil conservation, *Estimating, Forecasting, Equations, Erosion, Soil erosion, Suspended load, Deposition (Sediments), Methodology, Reservoirs, Land management, Farm management, Aerial photography, Curves.

The four basic procedures currently used in the Soil Conservation Service to estimate sediment yield depending on the environment and available data are: (1) gross erosion and sediment delivery ratio estimates, (2) predictive equations, (3) suspended sediment load measurements, and (4) sediment accumulation measurements. For verification, it is desirable to use more than one method.

76:04D-006
STOCHASTIC APPROACH TO THE COLORADO RIVER BASIN,
Lane, W.L., Gibbs, A.E., and Main, R.B.
Water Utilization Section, Bureau of Reclamation, Denver, Colorado
Presented at the National Water Resources and Ocean Engineering Convention of the American Society of Civil Engineers, 25 p, April 5-8, 1976, San Diego, California. 4 fig, 1 tab, 6 ref.

Descriptors: Hydrology, Rivers, River basins, River systems, Dissolved solids, Water quality, Colorado river, Colorado river basin, Salinity.

The stochastic approach to hydrology may be successfully applied to large river basins with several interdependent tributary inflows. Quality, specifically total dissolved solids, may be successfully generated jointly with flow. In actual application to the Colorado River Basin, results were obtained which are valuable for planning and evaluation purposes. By using stochastically generated flows and qualities, it is found that the effects of various structural or nonstructural measures in the basin may be more realistically assessed under a variety of potential future flow and salinity conditions. If the measures had been analyzed with the set of historical flows and salinities, the assessment would have been incomplete and biased. This approach is expected to be applicable to other basins with similar success.

SECTION XXIII

WATER QUALITY MANAGEMENT AND PROTECTION

IDENTIFICATION OF POLLUTANTS (GROUP 05A)

76:05A-001
EVALUATION OF METHODS FOR PRESERVING THE LEVELS OF SOLUBLE INORGANIC PHOSPHORUS AND NITROGEN IN UNFILTERED WATER SAMPLES,
Klingaman, E.D., and Nelson, D.W.
Purdue University, Agricultural Experiment Station, Lafayette, Indiana.
Journal of Environmental Quality, Vol. 9, No. 1, p 42-46, 1976. 3 tab, 11 ref.
(See 76:07B-006)

76:05A-002
REGIONAL CHARACTERISTICS OF THE TOTAL DISSOLVED MINERALS IN STREAM WATERS IN ILLINOIS,
Flemal, R.C., and Nienkerk, M.M.
Northern Illinois University, Department of Geology, DeKalb, Illinois.
Water Resources Bulletin, Vol. 12, No. 3, p 501-509, June 1976. 2 fig, 4 tab, 10 ref. S-046-ILL.

Descriptors: *Water chemistry, *Chemical analysis, *Illinois, *Dissolved solids, *Natural streams, *Mineralogy, Analytical techniques, Water analysis, Water quality, Water properties, Streams, Rivers, Surface waters, Urban runoff, Sulfates, Carbonates, Geology, Water pollution sources, Regions.

Using water analyses from 67 gaging stations, discharge-frequency-weighted mean concentrations and average annual yield per unit area were determined for the total dissolved mineral content of Illinois streams. The resultant data indicated that total dissolved mineral contents are controlled by regional rather than local factors. In most cases, plausible explanation for the magnitudes could be found in regional patterns of natural and demographic conditions. Although the data suggested that total dissolved minerals are increasing, the relative contributions of natural versus anthropogenic phenomena were difficult to delimit at this level of investigation.

76:05A-003
A SIMPLE TUBE-TYPE WATER PROFILE SAMPLER,
Gilbert, R.G., and Miller, J.B.
Agricultural Research Service, Water Conservation Laboratory, Phoenix, Arizona.
Water Resources Research, Vol. 12, No. 4, p 812-815, August 1976. 1 fig, 3 tab, 5 ref.

Descriptors: *Instrumentation, *Sampling, *Plastics, Farm ponds, Irrigation canals, Lakes, Ponds, Dissolved oxygen analyzers, Chemical analysis, Tubes, Water sampling, Agriculture, Pollutant identification.

A plexiglass tube-type water profile sampler was designed for use in relatively shallow bodies of water, such as farm ponds, small recreational lakes, irrigation canals, and the surface 2 m of larger lakes and rivers. The sampler was a plexiglass tube with holes drilled at intervals (side ports) corresponding to water layers which were to be sampled. To obtain a water sample, the tube (open at both ends and with the side ports closed) was gently lowered vertically into the water. With the top stoppered, the tube was raised and its bottom stoppered just under the water surface. While the tube was held vertically, the water profile samples were rapidly and easily obtained after removing the top stopper and successively collecting from top to bottom the water sample from each side port. Dissolved oxygen (DO) profiles of the ponds measured with an oxygen probe directly in the ponds were similar to DO profiles of water samples collected with the tube sampler. Chemical and biological analyses of water samples obtained with the tube-type sampler and two other standard type water samplers (Kemmerer and Van Dorn) were compared. The analyses revealed that similar relative results were obtained from water samples collected with all three samplers, but the tube-type sampler was more desirable for obtaining water profile samples because of its simplicity of design and operation especially in small ponds.

76:05A-004
A NOTE ON AN IN SITU GROUNDWATER SAMPLING PROCEDURE,
Spalding, R.F., Exner, M.E., and Gormly, J.R.
Nebraska University, Division of Natural Resources, Conservation and Survey, Lincoln, Nebraska.
Water Resources Research, Vol. 12, No. 6, p 1319-1321, December 1976. 2 fig, 1 ref.

Descriptors: *Sampling, *Samplers, *Groundwater, Water pollution, Well casings, *Pollutant identification.

In situ groundwater sampling can be a relatively economical procedure for measuring time, spatial and vertical changes in groundwater quality. The sampling technique cited allows large samples (1.1 liters) to be collected from a 2 foot vertical interval of the groundwater column. This sampling technique allows the quantification of the nature of groundwater contamination and allows for interpretation of areal sources and the extent of contamination.

76:05A-005
DETECTION OF TRENDS IN WATER QUALITY DATA FROM RECORDS WITH DEPENDENT OBSERVATIONS,
Lettenmaier, D.P.
Washington University, Department of Civil Engineering, Seattle, Washington.
Water Resources Research, Vol. 12, No. 5, p 1037-1046, October 1976. 11 fig, 3 tab, 12 ref, 1 append. NSF BMS74-20744.

Descriptors: *Water quality, *Time series analysis, *Statistical methods, Analytical techniques, Statistics, Data processing, Monte Carlo method, Markov processes, Temperature, Water temperature, Suspended solids, Conductivity, Water pollution, Pollutants, Model studies.

Classical statistical tests for trend, both parametric and nonparametric, assume independence of observations, a condition rarely encountered in time series obtained by using moderate to high sample frequencies. A method was developed for summarizing the power of the parametric t tests, the nonparametric Spearman's rho test, and Mann-Whitney's test against step and linear trends in a dimensionless "trend number" which is a function of trend magnitude, standard deviation of the time series, and sample size. For the case of dependent observations, use of an equivalent independent sample size rather than the actual sample size was shown to enable use of the same trend number developed for the independent case. An important related result is the existence of an upper limit on power (trend detectability) over a fixed time horizon, regardless of the number of samples taken, for a lag 1 Markov process.

76:05A-006
DESIGN AND OPTIMIZATION OF GROUNDWATER MONITORING NETWORKS FOR POLLUTION STUDIES,
Pfannkuch, H.O., and Labno, B.A.
Minnesota University, Department of Geology and Geophysics, Minneapolis.
Ground Water, Vol. 14, No. 6, p 455-462, November-December 1976. 6 fig, 2 tab, 5 ref.

Descriptors: *Network design, *Water pollution, *Groundwater, *Monitoring, Waste disposal, Waste dumps, Networks, Planning, Wells, Observation wells, Sampling, Leachate, Chemical analysis, Water pollution, Pollutants, Geology, Leaching, Aquifers, Hydrogeology.

The successful design and operation of a groundwater monitoring and surveillance system were based on a stepwide process of obtaining hydrogeologic information. Because of the inherent uncertainty and inhomogeneity of natural hydrogeological systems, the true monitoring network cannot be specified before some basic knowledge about system configuration and dynamics is known. Forethought, planning, and incorporation of design criteria as part of the initial phase of project management establishes the monitoring network strategy. Optimization of the monitoring network takes place through the completion of the following five phases: (1) preliminary network design and information gathering, (2) initial installation and testing, (3) completion and verification, (4) operational, and (5) project termination. Experience gained from monitoring the conditions at the University of Minnesota's chemical and special waste disposal site resulted in the design and optimization procedure. Concern for possible groundwater contamination led to analysis of surface and subsurface, physical and chemical conditions. Subsequently, a monitoring system was established to meet project objective. No degradation of the groundwater was found during the five-year study.

76:05A-007
MONITORING GROUND-WATER QUALITY NEAR A SANITARY LANDFILL,
Kunkle, G.R., and Shade, J.W.
Earthview, Incorporated, Toledo, Ohio.
Ground Water, Vol. 14, No. 1, p 11-20, January-February 1976. 8 fig, 2 tab, 18 ref.

Descriptors: *Water quality, *Groundwater, *Landfills, *Leachate, *Monitoring, *Michigan, Groundwater Movement, Water pollution, Sulfur bacteria, Carbonates, Chemical Degradation, Reduction (chemical), Oxidation-reduction potential, Path of pollutants, Pollutants.

At the Hagman Road Landfill refuse is buried in lacustrine and glacial till deposits consisting mainly of silty clays. These clays overlie a thick carbonate aquifer used locally for water supply. The dominant direction of groundwater flow is vertically down. Time of groundwater travel from the refuse to the aquifer was estimated at 12 years, putting first arrivals in 1978. Water quality monitoring of bedrock waters showed decreases in total dissolved solids, sulfates, calcium, magnesium, chlorides, and total hardness with increases in alkalinity to exist locally beneath the landfill. The principal chemical reaction felt to explain some, but not all, of the water quality changes in sulfate reduction. Theoretical geochemical modellings helped to support this interpretation. The landfill was hypothesized to have either triggered or accelerated sulfate reduction by creating the reducing environment.

76:05A-008
PROBLEMS IN PREDICTING AND MEASURING SOLUTE CONCENTRATIONS IN IRRIGATED FIELDS,
Jury, W.A., Fluhler, H., and Stolzy, L.H.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 246-263. 11 fig, 4 tab, 5 ref.

Descriptors: Salinity, Salts, Root zone, Irrigation practices, Simulation analysis, Model studies.

The observed variation in salt concentration found between sensors at comparable depths has been shown to be influenced far more by avriability in the water uptake distribution than by changes in the assumed conductivity of the soil or by input variations. This places severe restrictions on simulation of water and salt movement within the root zone. At the same time, however, it suggests that calculation of material transport below the root zone may not be as severely limited by uncertainty in the soil transport coefficients as had previously been suggested, provided that one can obtain reliable estimates of input water volumes and plant and soil evaporation. Finally, the period of transition between new and old irrigation management can be quite long, during which time reliance on soil sensors to provide feedback for irrigation levels is likely to cause great errors.

76:05A-009
WATER QUALITY AND RETURN FLOW STUDY OF THE OAHE UNIT, SOUTH DAKOTA,
Keys, J.W., III.
United States Bureau of Reclamation, Engineering and Research Center, Colorado River Water Quality Office.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 109-126. 3 fig, 2 tab, 6 ref.

Descriptors: Water quality, Return flow, South Dakota, Simulation analysis, Seepage, Dissolved solids, Water quality control.

The Oahe Unit of the Pick-Sloan Missouri Basin Program will provide Missouri River water for the irrigation of 190,000 acres of land in the James River Valley of South Dakota. Computer simulation studies of the operation of the Unit were conducted to estimate the quantity, quality, and timing of irrigation return flows and determine their effects on the James River. This analysis included detailed investigations of the irrigation water and lands to be irrigated, the major augmentation releases of water to the James River, natural flow of the river, and operation of project features for storage and regulation of water for irrigation of the Unit. Under natural conditions, total dissolved solids (TDS) levels of James River streamflow are relatively high, averaging about 786 mg/l at Huron. Study results show that TDS levels of the river could be maintained below 1,000 mg/l (current South Dakota water quality standard for the river reach immediately below the project) during the irrigation season, but concentrations during the winter season would frequently exceed that level. Streamflow would be stabilized, however, eliminating very low and highly concentrated flows.

76:05A-010
EFFECTS OF IRRIGATION LEACHING MANAGEMENT ON RIVER AND SOIL WATER SALINITY,
Saurez, D.L., and Rhoades, J.D.
United States Salinity Laboratory, Riverside, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 95-108. 5 tab, 8 ref.

Descriptors: Irrigation, Irrigation systems, Irrigation efficiency, Soil water, Groundwater, River systems, River basins, Leaching, Salinity, Saline water.

Information about the effects of irrigation management on the changes in river water, soil water, and groundwater quality associated with successive downstream water diversion for representative types of river waters is provided. The deposition of CaCO3 and gypsum in entire river basins as a function of leaching fraction is also considered.

76:05A-011
MANAGING SALINE WATER FOR IRRIGATION,
Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Lubbock, Texas.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976. 618 p.
(see 76:05C-002)

76:05A-012
VARIOUS INDICES FOR EVALUATING THE EFFECTIVE SALINITY AND SODICITY OF IRRIGATION WATERS,
Oster, J.D., and Rhoades, J.D.
Unites States Salinity Laboratory, Riverside, California
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 1-14. 5 fig, 2 tab, 20 ref.

Descriptors: Irrigation water, Salinity, Saline water, Simulation analysis, Model studies.

The salinity and sodicity hazards of irrigation water were evaluated by several methods including residual sodium carbonate, pHc * and a computer cimulation of gypsum and aragonite precipitation based on an assumed water uptake and PCO2 distribution through the root zone. No useful correlation was found between the computer predicted relative calcium and bicarbonate precipitation and residual sodium carbonate. A correlation of r as similar or equal to 0.7 was found for pHc*. Relative calcium precipitation was correlated, r as similar or equal to 0.8, with (CCa)(CSO4), where C is concentration (meq/l) in the irrigation water, when the product exceeded 30. The SAR's calculated from pHc* and the simulation model, for the soil surface and bottom of the root zone, were also correlated, r is equal to 0.99.

76:05A-013
WATER QUALITY FOR AGRICULTURE,
Ayers, R.S., and Westcot, D.W.
California University, Department of Land, Air, and Water Resources, Davis, California
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 400-431. 4 tab, 73 ref.

Descriptors: Water quality, Agriculture, Crop production, Salinity, Soil water, Saline soil, Saline water, Leaching, Sodium, Water supply.

Salinity is discussed from the standpoint of a reduction in soil water availability to crop. Updated crop tolerance tables for salinity of soil or of applied water are presented. The newer leaching requirement concept of achievable represents a considerable water saving as compared to the older LR procedures. Soil permeability problems are associated with waters having either exceptionally low salinity or high sodium. Excessive sodium is evaluated through a modification of the sodium adsorption ratio (SAR), now termed 'adjusted SAR'. Specific ion toxicities are related to the effects of boron, sodium or chloride on sensitive crips. A few other effects are listed under 'miscellaneous problems'. This paper is intended to provide guidance for project managers, farm operators, and general agriculturalists on problems related to on-farm water management and should be useful in placing water quality effects in perspective with the other factors affecting crop production, the ultimate goal being maximum production per unit of available water supply.

76:05A-014
MINIMIZING THE SALT BURDEN OF PECOS RIVER IRRIGATION DRAINAGE WATER,
O'Connor, G.A., and Cull, C.
New Mexico State University, Department of Agronomy, Las Cruces, New Mexico
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 494-505. 9 fig, 2 tab, 5 ref.

Descriptors: Leaching, New Mexico, Lysimeters, Irrigation, Irrigation effects, Evaporation, Water surface, Return flow, Drainage, Drainage effects.

A laboratory study was conducted to evaluate the potential of the minimized leaching concept using synthesized Pecos River water on a New Mexico soil. Nine small lysimeters were repeatedly irrigated at LFs of 0.1, 0.2, and 0.4 and exposed to very high evaporative demands in an evaporation chamber especially designed for the study. Results to date (after 50 irrigations) confirm that minimized leaching results in considerable irrigation water savings and a simultaneous reduction in drainage volume. Even after prolonged irrigation, steady-state conditions have been reached in only the 0.4 LF treatment implying that changes in salt distribution as a result of instituting the minimized leaching program are very slow to occur.

SECTION XXIV

WATER QUALITY MANAGEMENT AND PROTECTION

SOURCES AND FATE OF POLLUTION (GROUP 05B)

76:05B-001
SURFACE RUNOFF LOSSES OF FERTILIZER ELEMENTS,
Dunigan, E.P., Phelan, R.A., and Mondart, C.L. Jr.
Louisiana State University, Department of Agronomy, Baton Rouge, Louisiana; and
Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana.
Journal of Environmental Quality, Vol. 5, No. 3, p 339-342, 1976. 6 tab, 9 ref.

Descriptors: *Nitrogen compounds, *Phosphorus compounds, *Fertilizers, *Nutrient removal, *Agricultural runoff, *Louisiana, Nitrogen, Ammonia, Nitrates, Phosphates, Potassium compounds, Leaching, Potash, Runoff, Water quality, Water pollution, Analytical techniques, Surface runoff, On-site investigations.

Surface runoff losses of fertilizer N, P, and K were measured from a Loring silt loam soil with an average slope of 5%. Plots seeded to pearl millet in 1973 and 1974 were fertilized at the rate of 112-49-93 kg/ha of incorporated N, P, and K using two different fertilizer blends, a 33.3-8.7-16.6 and an 8-3.5-6.6. The percent of water-soluble fertilizer elements lost in 1973 from the higher and lower blend concentrations, respectively, were N, 0.50 and 0.30%; P, 0.14 and 0.06% and K, 0.67 and 0.92%. In 1974, N losses were 0.89 and 0.14%; P, 0.35 and 0.20%; and K, 0.42 and 0.35%. Precipitation during the experimental periods was 20.40 cm in 1973 and 27.69 cm in 1974. Ryegrass plots were fertilized with sulfur-coated urea (SCU) and uncoated urea (U) at the rate of 224 kg N/ha during the growing seasons of 1973 and 1974. Total N losses (U vs. SCU) were 9.52 and 0.26% in 1973, and 1.67 and 0.42% in 1974. A 10.08-cm rainfall on the third day of the test in 1973 caused almost three-fourths of the 9.52% N lost from the uncoated urea to be lost in that runoff and while it was still in the urea form. The sulfur coating prevented large surface losses of N from the SCU.

76:05B-002
NITROGEN IN SUBSURFACE DISCHARGE FROM AGRICULTURAL WATERSHEDS,
Burwell, R.E., Schuman, G.E., Saxton, K.E., and Heinemann, H.G.
Agricultural Research Service, Columbia, Missouri.
Journal of Environmental Quality, Vol. 5, No. 3, p 325-329, 1976. 4 fig, 3 tab, 15 ref.

Descriptors: *Nitrogen, *Subsurface runoff, *Agricultural watersheds, *Nutrient removal, *Nitrogen compounds, *Iowa, Fertilizers, Leaching, Nutrients, Analytical techniques, Percolation, Water quality, Groundwater, Nitrates, Soil erosion, Water pollution sources, Soil conservation, Runoff, Watersheds (Basins), Conservation, Sediment discharge.

The nitrogen in subsurface discharge and surface runoff was measured from four agricultural watersheds on Missouri Valley deep loess near Treynor, Iowa, from April 1969 through March 1974. The data showed that, with the agricultural management practices used on the watersheds, the subsurface discharge of water ranged from 62 to 88% of the average annual stream flow. Nitrate in subsurface discharge accounted for 84 to 95% of the total average annual soluble N discharged in stream flow. A terraced watershed continuously cropped to corn had reduced surface runoff, sheet-rill erosion, and associated nitrate-nitrogen discharge, but had increased subsurface discharge of water and soluble N as compared with two contoured corn watersheds. Nitrogen fertilizer applied at a high rate (448 kg/ha/year) exceeding crop needs on the terraced and contoured watersheds, increased five- and threefold the average annual subsurface discharge of NO3-N, respectively, as compared with a contoured watershed fertilized with N at a normal rate (168 kg/ha/year). Controlling the watershed discharge of N and subsequent pollution of stream flow from the Iowa and Missouri deep loess hills requires N fertilizer application rates that do not exceed crop needs and using conservation practices that minimize soil erosion and deep percolation.

76:05B-003
GEOLOGIC NITROGEN IN PLEISTOCENE LOESS IN NEBRASKA,
Boyce, J.S., Muir, J., Edwards, A.P., Seim, E.C., and Olson, R.A.
Nebraska University, Department of Agronomy, Lincoln, Nebraska.
Journal of Environmental Quality, Vol. 5, No. 3, p 93-96, January-March 1976.
3 fig, 1 tab, 15 ref.

Descriptors: *Nitrogen, *Nitrates, *Soil contamination, *Nebraska, *Soils, *Loess, Fertilization, Fertilizers, Agricultural chemicals, Water pollution, Leaching, Irrigation, Cores, Soil chemical properties, Geology, Limestones, Shales, Groundwater.

Research into the relationship between fertilizer use and water quality in Nebraska has resulted in the discovery of large quantities of geologic nitrate within the deep loess mantle of southwestern and central Nebraska. The NO3(-) was first encountered at a depth of about 7 m and continued to an unknown depth in excess of 30 m. Nitrate-N values of 25 to 45 ppm characterized the N zone, but values to 87 ppm have been recorded. The NO3(-) existed only under the more level uplands of the region; however, it is on this plain that rapid development of irrigation is taking place, and it has been shown that the NO3(-) has been leached from beneath older irrigation sites on the plain.

76:05B-004
DISPOSITION OF FERTILIZER NITRATE APPLIED TO A SWELLING CLAY SOIL IN THE FIELD,
Kissel, D.E., Smith, S.J., and Dillow, D.W.
Texas Agricultural Experiment Station, College Station, Texas.
Journal of Environmental Quality, Vol. 5, No. 3, p 66-71, January-March 1976.
4 fig, 3 tab, 19 ref.

Descriptors: *Nitrogen compounds, *Nitrates, *Fertilizers, *Leaching, *Soil chemistry, Water quality, Analytical techniques, Leachate, Drainage, Nutrients, Runoff, Subsurface drainage, Water pollution sources, Nutrient removal, Water pollution, Percolation, Infiltration, Lysimeters, Drainage water, Grain sorghum, Root zone, Path of pollutants.

This study was prompted by the present controversy over the role that N-fertilizer use may have in reducing water quality. The objective was to determine the disposition of N fertilizer (enriched with 15N) applied to level (less than 2% slope) Houston Black clay near the economic optimum application rate (112 kg N/ha) for grain sorghum. Particular emphasis was placed on determining the amount of applied N which leached below the root zone at different times during and after the growing season. A large, undisturbed field-drainage lysimeter was used to measure leaching of NO3(-)-N below the root zone. During spring 1973, 94 mm of drainage water containing a mean concentration of 2.4 ppm fertilizer-derived NO3(-)-N percolated through the soil profile. At crop maturity, only 55% of the N applied the previous spring was recovered by the crop or was present in drainage water. Large amounts of N not recovered by the crop were either measured as immobilized N (20% of the applied N) or were unrecovered and assumed denitrified (17%). During the fall and winter, approximately 120 mm of drainage water containing 0.5 ppm or less fertilizer-derived NO3(-)-N percolated through the soil profile. These results indicated that for rainfall conditions observed in this study (minimal crop water deficit), the application of N fertilizer to grain sorghum at the near-optimum economic rate probably would not seriously reduce groundwater quality on a swelling clay soil, even though crop recovery of applied N might be low.

76:05B-005
NITROGEN BALANCE IN THE SOUTHERN SAN JOAQUIN VALLEY,
Miller, R.J., and Smith, R.B.
California University, Department of Land, Air, and Water Resources, Water Science and Engineering Section, Davis, California.
Journal of Environmental Quality, Vol. 5, No. 3, p 274-278, July-September 1976.
2 fig, 5 tab, 21 ref.

Descriptors: *Nitrate, *Nitrogen, *California.

A nitrogen balance for the southern San Joaquin Valley of California has been calculated, using techniques and methodology developed for the Upper Santa Ana

River Basin of southern California. The two areas differed considerably in both size (the latter being much smaller) and agricultural function. Data were compiled on N inputs, use, and outputs for many sources within the study area. Such data enabled construction of a flow diagram depicting best estimates of N pools and fluxes within the San Joaquin Valley Basin. Results show N inputs into the study area from various sources were somewhat greater than output to the atmosphere and by plant removal. Inputs to the soul N pool were about 9 kg/ha more in 1971 than in 1961. Since the soil N pool was estimated to be about 11 metric tons/ha, this represented an increase of about 0.1%. However, since the increases of N are not evenly distributed over the study area, high N concentrations can develop in some local areas.

76:05B-006
RESIDUES OF DICHLOBENIL IN IRRIGATION WATER,
Bowmer, K.H., O'Loughlin, E.M., Shaw, K., and Sainty, G.R.
Commonwealth Scientific and Industrial Research Organization, Division of Irrigation Research, Griffith, New South Wales, Australia.
Journal of Environmental Quality, Vol. 5, No. 3, p 315-319, July-September 1976. 3 fig, 4 tab, 15 ref.

Descriptors: *Herbicides, *Irrigation canals, Irrigation effects, Irrigation, Aquatic weeds, Crop production.

Field trials were made on two inlined irrigation channels to measure the extent of water contamination due to residues of dichlobenil which had been applied to the empty channel the previous winter. Ten weeks after application, the herbicide remaining in the soil was about 6% of the initial application. About 4 months after application, water was passed through the channels and wasted into drains. The maximum herbicide concentration in this flushing water was 0.18 ppm and was judged to present no potential hazard to crops. The need for prolonged channel flushing is questioned. An alternative procedure, displacing the static water in the channel following by a period of ponding, is suggested as a means of avoiding high herbicide residues in irrigation water.

76:05B-007
SIMPLIFIED LONG TERM CONCEPT FOR EVALUATING LEACHING OF NITROGEN FROM AGRICULTURAL LAND,
Fried, M., Tanji, K.K., and Van De Pol, R.M.
Food and Agriculture Organization, International Atomic Energy Agency Division, Vienna, Austria.
Journal of Environmental Quality, Vol. 5, No. 2, p 197-200, April-June 1976. 5 fig, 1 tab, 17 ref.

Descriptors: *Leaching, *Nitrogen, Crop production, Groundwater, Water quality, Pollutants, Fertilizers, Nutrients.

A rather simple concept is proposed for predicting the contribution of crop production practices to groundwater N pollution. It is a steady state long term concept. One of the consequences is that the myriad reactions that take place in the soil body itself need not be evaluated. Application of this concept indicates that, in general, the single most important practice under man's control that affects potential pollution is fertilizer use efficiency. As long as yield response is obtained to N fertilizer additions, fertilizer should contribute lesser amounts of N to the groundwater providing fertilizer use efficiency is maintained at a high level.

76:05B-008
CONCENTRATION AND DISTRIBUTION OF ELEMENTS IN PLANTS AND SOILS NEAR PHOSPHATE PROCESSING FACTORIES, POCATELLO, IDAHO,
Severson, R.C., and Gough, L.P.
United States Geological Survey, Box 25046, Denver Federal Center, Denver, Colorado.
Journal of Environmental Quality, Vol. 5, No. 4, p 476-482, October-December 1976. 5 fig, 4 tab, 19 ref.

Descriptors: *Idaho, *Phosphate, *Shales, Soils, Sagebrush, Sediments, Nickel, Elements.

The processing of phosphatic shale near Pocatello, Idaho has a direct influence on the element content of local vegetation and soil. Samples of big sagebrush and cheatgrass show important negative relations between the concentration of certain elements (Cd, Cr, F, Ni, P, Se, U, V, and Zn) and distance from phosphate processing factories. Plant tissues within 3 km of the processing factories contain unusually high amounts of these elements except Ni and Se. Important negative relations with distance were also found for certain elements (Be, F, Fe, K, Li, Pb, Rb, Th, and Zn) in A-horizontal soil. Amounts of seven elements (Be, F, Li, Pb, Rb, Th, and Zn) being contributed to the upper 5 cm of the soil by phosphate processing, as well as two additional elements (U and V) suspected as being contributed to soil, were estimated, with F showing the greatest increase (about 300 kg/ha) added to soils as far as 4 km downwind from the factories. The greatest number of important relations for both plants and soils was found downwind (northeast) of the processing factories.

76:05B-009
PHOSPHORUS LOSS BY STREAM TRANSPORT FROM A RURAL WATERSHED: QUANTITIES, PROCESSES, AND SOURCES,
Johnson, A.H., Bouldin, D.R., Goyette, E.A., and Hedges, A.M.
Pennsylvania University, Philadelphia, Pennsylvania.
Journal of Environmental Quality, Vol. 5, No. 2, p 148-157, April-June 1976.
12 fig, 5 tab, 12 ref.

Descriptors: *Phosphorus, *New York, Low flow, Surface runoff, Sediments, Farm waste, Sampling, Watersheds (basins), Land use.

Loss of dissolved and particulate phosphorus by stream transport was determined over a 20-month period for Fall Creek, a stream draining a predominantly rural watershed of 330 sq km in central New York. Samples were taken several times daily during most high flow periods and at 3 to 20 day intervals during low flow periods. Samples were ususlly processed within 4 hours since redistribution of P among chemical forms was rapid. Losses of P from the watershed per unit time varied by several orders of magnitude and 75% of the P loss occurred in the major point source inputs, dissolved inorganic P concentrations were highest during storm events due to two processes: desorption of P accumulated in the bed sediment from point source inputs during low flow, and inputs from diffuse sources in surface runoff. Dissolved organic P concentrations were not correlated with flow. Approximately 20% of the dissolved P lost from the watershed was derived from diffuse sources associated with farming, 45% was derived from natural geochemical processes, and 35% from point source inputs. Less than 1% of the P applied to the landscape in chemical fertilizer and manure was lost from the watershed in dissolved form.

76:05B-010
SOIL NITRATES FOLLOWING FOUR YEARS CONTINUOUS CORN AND AS SURVEYED IN IRRIGATED FARM FIELDS OF CENTRAL AND EASTERN COLORADO,
Ludwick, A.E., Reuss, J.O., and Langin, E.J.
Colorado State University, Department of Agronomy (Soils), Fort Collins, Colorado.
Journal of Environmental Quality, Vol. 5, No. 1, p 82-86, January-March 1976.
4 fig, 3 tab, 18 ref.

Descriptors: *Fertilizers, *Nitrogen, *Groundwater, Pollutants, Corn, Irrigation effects, Colorado, Fertilization, Nutrients, Soil texture, Beans.

High rates of fertilizer N used in many intensive farm management systems have been cited as a potential pollution hazard to surface and ground waters. The purpose of this study was to evaluate soil $NO_3(-)$ accumulations following 4 years continuous corn grown with different nitrogen and irrigation regimes, and to compare these results to present $NO_3(-)$ concentrations found in irrigated farm fields of central and eastern Colorado. Soil $NO_3(-)$ content in the 300-cm sampled profile was significantly influenced by both fertilizer N and irrigation treatments; the greater accumulations were associated with the two higher fertilizer N rates and two lower irrigation rates. Nitrate increased linearly in relation to fertilizer N between 67 and 269 kg N/ha and could be described by two simple regression equations separating the irrigation treatments into two groups (1-2 and 1-3, low rates; 1-4 and 1-5, high rates). Coefficients of determination for the two groups were 0.981 and 0.975, respectively.

76:05B-011
NITRATE DYNAMICS IN FALL CREEK, NEW YORK,
Johnson, A.H., Bouldin, D.R., Goyette, E.A., and Hedges, A.M.
Pennsylvania University, Regional Planning Division, Philadelphia, Pennsylvania.
Journal of Environmental Quality, Vol. 5, No. 4, p 386-391, October-December 1976. 5 fig, 3 tab, 11 ref.

Descriptors: *Watersheds (basins), New York, Leaching, Water quality, Farm wastes, Agriculture.

Nitrate loss from a 330 sq km rural watershed in central New York was monitored over a 31-month period. Seasonal NO3-N patterns were well defined with highest levels in the winter and lowest levels in the summer resulting from accumulation of NO3-N in the soil profile during the growing season and leaching during the winter months. Stream water at the outlet of the watershed studied is used as a source of drinking water for some 20,000 people. Nitrate-N concentrations at the drinking water intake currently do not exceed 3 mg/liter. Human activities affected NO3-N levels, with dairying and sewage being the major contributors. If agriculture is expanded to its maximum acreage, keeping the present ratio of corn/hay/pasture/people, NO3-N levels at the drinking water intake will not exceed present standards for drinking water.

76:05B-012
MOVEMENT OF FERTILIZER AND HERBICIDE THROUGH IRRIGATED SANDS,
Mansell, R.S., Rhoads, F.M., Hammond, L.C., Selim, H.M., and Wheeler, W.B.
Florida University, Department of Soil Science, and Florida University, Gainesville Institute of Food and Agriuclture, Gainesville, Florida.
Available from the National Technical Information Service, Springfield, Virginia, and PB-261 505, Price codes: A04 in paper copy, A01 in microfiche.
Florida Water Resources Research Center, Gainesville, Publication No. 38, September 10, 1976. 50 p, 21 fig, 4 tab, 20 ref, append. OWRT A026-FLA(10).
14-34-0001-6010.

Descriptors: Infiltration, Irrigation, Herbicides, Fertilizers, Kinetics, Sorption, Soils, Path of pollutants, *Sands, *Florida, Irrigated land, Leaching.

The simultaneous movement of water and selected agrichemicals (fertilizer nutrients and herbicide) through sandy soils is of particular importance to the efficient use of fertilizers and irrigation water by agricultural crops. Efficient use of fertilizers and herbicides applied to Florida's sandy soils is desirable for maintaining optimum growth of plants and for minimizing groundwater contamination. Laboratory and field experiments as well as mathematical models were used to study water and solute (potassium and phosphorus nutrients and 2,4-D herbicide) transport in two representative Florida soils: Wauchula sand and Troup sand. In an irrigated and fertilized corn experiment, grain yields and efficiency of water use were observed to be mutually related to both the irrigation and the fertilizer application treatments. Leaching of applied nutrients and irrigation water from the soil "rooting zone" resulted in decreased water use efficiency in these soils. Mathematical models were developed and used to simulate transport and chemical-physical reactions for potassium, phosphorus and 2,4-D herbicide in these soils. Reactions such as adsorption-desorption, chemical precipitation and immobilization (fixed) greatly influenced the movement and thus potential leaching of these solutes through the soil.

76:05B-013
THE POTENTIAL CONTRIBUTION OF FERTILIZERS TO WATER POLLUTION,
Douglas, L.A.
Rutgers-The State University, Department of Soils and Crops, New-Brunswick, New Jersey.
Available from the National Technical Information Service, Springfield, Virginia, as PB-259 609, Price codes: A05 in paper copy, A01 in microfiche. Water

Resources Research Institute, Rutgers University, New Brunswick, New Jersey
Partial Completion Report June 1976. 92 p, 50 fig, 16 tab, 45 ref. OWRT A-027-NJ(6). 14-31-0001-3830.

Descriptors: *Nitrates, *Nitrites, *Ammonia, *Phosphates, *Leaching, *Fertilizers, Land use, *New Jersey, *Denitrification, Nitrogen, Nutrients, Water pollution sources.

Field studies were undertaken to determine the magnitude of leaching of fertilizer NO3, NH4 and PO4. The effect of N-SERVE on these reactions was observed, N-SERVE had little effect on leaching because most leaching takes place during the fall and winter when precipitation exceeds evapotranspiration. No leaching of NH4 or PO4 was observed. The common fertilizer efficiency measure of N in crop/N applied in fertilizer may be used as an indication of the amount of fertilizer N that will be leached. Studies of nutrients in streams were undertaken to relate land use to NO3, NH4, and PO4 concentrations in surface waters. Sewage treatment plants and "illegal drains" were major sources of all three ions. In order of decreasing contribution of NO3: urban land contributes more than cropland which contributes more than woodlands. Urban lands, croplands and woodlands contribute equal amounts of NH4 and PO4 to streams. The "background level" of PO4 in central New Jersey streams is many times higher than the 0.01 ppm level often advocated. Although very high concentrations of NO3 were found in the soil solution in the subsoil the concentration of NO3 found in streams was rather low. Denitrification must be an active process in subsoils, and probably in the groundwater.

76:05B-014
PREDICTING 2,4,5-T MOVEMENT IN SOIL COLUMNS,
O'Connor, G.A., van Genuchten, M. Th., and Wierenga, P.J.
New Mexico State University, Las Cruces, New Mexico.
Journal of Environmental Quality, Vol. 5, No. 4, p 375-378, October-December 1976. 8 fig, 1 tab, 9 ref.

Descriptors: *Model studies, *Effluents, *Tritium, 2,4,5-T, Soils, Soil investigations, Adsorption, Pesticides, Herbicides.

A solute model developed by van Genuchten and Wierenga was used to calculate 2,4,5-T effluent data from soil columns. The model had been previously shown to adequately predict effluent data given model parameters curve fit to a portion of the effluent curve. The present work shows that 2,4,5-T effluent curves may be adequately predicted without prior knowledge of the effluent curves for a particular soil column given: (i) model parameters derived from 2,4,5-T effluent curves for other soil columns, or (ii) model parameters obtained from tritium effluent curves for the same columns. The data suggest that once the physical model parameters have been characterized for a soil, reasonable predictions of 2,4,5-T (and perhaps other solutes) transport can be made given the adsorption coefficient for the solute.

76:05B-015
DISTRIBUTION OF PLUTONIUM IN TRINITY SOILS AFTER 28 YEARS,
Nyhan, J.W., Miera, F.R. Jr., and Neher, R.E.
Los Alamos Science Laboratory, Soil Science, Los Alamos, New Mexico.
Journal of Environmental Quality, Vol. 5, No. 4, p 431-437, October-December 1976. 6 fig, 4 tab, 22 ref.

Descriptors: Soils, Soil investigations, Nuclear wastes, Nuclear explosions, Sampling, Soil horizons, Soil profiles, Carbonates.

The soils of four intensive study areas located along the fallout pathway of Trinity, the first nuclear detonation, were sampled to determine soil plutonium concentrations as a function of distance from Ground Zero and soil depth. About half of the 239,240Pu in Trinity soils was found at the 5-20 cm depth in 1973 compared to total plutonium inventories found only in the upper 5 cm of soil about 20 years ago. Soil plutonium concentrations of samples collected at the same depth of each study area generally exhibited coefficients of variation > 1.2. Maximum penetration depths of 239,240Pu into Trinity Site soils were related to the presence of subsoil horizons containing carbonate accumulations and the maximum extent of rainwater penetration into these soil profiles.

76:05B-016
SALT AND WATER BALANCE IN IMPERIAL VALLEY, CALIFORNIA,
Kaddah, M.T., and Rhoades, J.D.
Imperial Valley Conservation Research Center, Brawley, California.
Soil Science Society of America Journal, Vol. 40, No. 1, p 93-100, January-February 1976. 4 fig, 2 tab, 13 ref.

Descriptors: *Salinity, *Salt balance, *Salts, Soil salinity, Water salinity, Root zone, Ground water, Surface runoff, Effluents, Water quality, California.

Salt balance of the Imperial Valley has been determined annually since 1943 by the Imperial Irrigation District. Salinity trends in the valley are assessed from biweekly measurements of the volume, V, and concentration, C, of influent inf.w, and effluent, eff.w, waters. This paper summarized the SB (Salt Balance) data, evaluates their significance, and suggests approaches for assessing salinity trends in the soils of the valley. The SB data reflected the cropping and water use patterns in the valley. However, the data were insufficient to distinguish origin of water and salt in effluent water or to provide information about changes in root zone salinity. In 1973 total evapotranspiration (ET) by crops in the valley was estimated to be 229 multiplied by 1,000 ha-m, equivalent to 70% of the water delivered to the farmers. Deductions as to Cl(-) composition of influent and effluent during 1973 suggest that the Cl(-) load in the effluent water was contributed as follows: 54.7% from ground water, 35.0% from root zone drainage water, and 10.3% from tail water (runoff).

76:05B-017
MOVEMENT OF CARBARYL THROUGH CANGAREE SOIL INTO GROUND WATER,
LaFleur, K.S.
Clemson University, Department of Agronomy and Soils, Clemson, South Carolina.
Journal of Environmental Quality, Vol. 5, No. 1, p 91-92, January-March 1976.
1 fig, 3 tab, 6 ref.

Descriptors: Soil profiles, Ground water, Pollutants, Soil investigations.

Carbaryl was applied to a Congaree sandy loam fieldplot containing a shallow (about -1.1 m) water table. Movement and loss in the soil profile, and accumulation in underlying ground water were monitored for 16 months. Rainfall during this time was 182 cm (3.5 pore volumes based on the upper 1 m of soil). The upper 1 m contained about 6% of the applied carbaryl after 16 months. No carbaryl was found in the 0-20 cm layer after the 4th month. Loss of carbaryl with time in the upper 1 m was concentration-dependent. Time to half-concentration within the upper 1 m was < 1 month. Carbaryl appeared in the underlying ground water within 2 months after soil application and persisted through the 8th month. Maximum ground water concentration, about 0.3 micromol/liter, occurred at the end of the second month.

76:05B-018
LOSSES OF NITROGEN IN SURFACE RUNOFF IN THE BLACKLAND PRAIRIE OF TEXAS,
Kissel, D.E., Richardson, C.W., and Burnett, E.
Texas A and M University, Texas Agricultural Experiment Station, College Station, Texas.
Journal of Environmental Quality, Vol. 5, No. 3, p 288-293, July-September 1976.
1 fig, 4 tab, 16 ref.

Descriptors: *Clays, *Nitrogen, *Texas, Fertilization, Watersheds (basins), Runoff, Pollution, Surface runoff.

The objective of this study was to determine NO3(-)-N and total N losses in surface runoff from Houston Black clay, a swelling clay soil with a relatively low infiltration rate. The study was carried out on duplicate 4-ha watersheds cropped to a rotation of grain sorghum, cotton, and oats, all fertilized at recommended rates of N application. The loss of NO3(-)-N varied considerably during the study, depending on events before each runoff-producing storm. Concentrations of NO3(-)-N were usually highest just after fertilizer application when the soil was near field capacity and lowest when large amounts of water infiltrated into dry soil immediately before runoff. During runoff-producing storms just after fertilizer application, the concentrations were lowest in the initial runoff and highest near the end of the runoff event. To compute NO3(-)-N losses with reasonable accuracy on these soils, the shape of the entire NO3(-)-N concentration curve needed to be well defined. In general, the results of this study indicate that a small and probably insignificant amount of N is lost to surface waters when crops are fertilized at recommended N rates in the Texas Blackland Prairie. For the entire 5-year study, the mean concentration of NO3(-)-N in runoff was 2.9 and 2.3 ppm NO3(-)-N for the duplicate watersheds. The mean total loss of NO3(-)-N was 3.2 kg ha (-1) year(-1). Losses of sediment associated N were about 5 kg N ha(-1) year(-1).

76:05B-019
THE IMPACT OF FERTILIZER USE AND CROP MANAGEMENT ON NITROGEN CONTENT OF SUBSURFACE WATER DRAINING FORM UPLAND AGRICULTURAL WATERSHEDS,
Chichester, F.W.
United States Department of Agriculture, Agricultural Research Service, Temple, Texas.
Journal of Environmental Quality, Vol. 5, No. 4, p 413-416, October-December 1976. 2 fig, 3 tab, 13 ref.

Descriptors:*Nitrogen, *Fertilizers, Fertilization, Agricultural Watersheds, Ohio, Sampling, Land management, Water quality, Deep percolation, Groundwater, Soils, Spring waters, Hydrogeology.

Spring flow and stream base flow sites were sampled weekly on and adjacent to a 123-ha agricultural watershed in the Allegheny-Cumberland Plateau physiographic region of east-central Ohio. Nitrogen content of samples was used to determine the influence of various N fertilizer and crop management practices on the quality of subsurface water draining from defined contributing areas. Measured nitrogen contents of spring flow were related to fertilizer N regime of the different agricultural practices investigated. Changes in land management on the area contributing to spring flow were reflected in changes in nitrogen content of water from that spring. The amount of nitrogen which was transported into the stream channel was directly related to seasonal variation in subsurface flow rate in two ways. First, the concentration of N in spring flow increased with an increase in the amount of water percolating through the overlying soil and shale. Second, the extent to which downstream quality was affected, i.e., the distance from the area of fertilizer application at which an increase in nitrogen content could be detected, also increased with the volume of flow from the springs.

76:05B-020
CHEMICAL DISTRIBUTION AND GASEOUS EVOLUTION OF ARSENIC-74 ADDED TO SOILS AS DSMA-(74)AS,
Akins, M.B., and Lewis, R.J.
Tennessee University, Department of Plant and Soil Science, Tennessee Agricultural Experiment Station, Knoxville, Tennessee.
Soil Science Society of America Journal, Vol. 40, No. 5, p 655-658, September-October 1976. 5 tab, 17 ref.

Descriptors: Arsenic compounds, Organic matter, Soil moistures, Soils, Soil investigations.

Gaseous evolution of (74)As from a soil treated with arsenic-74 labeled disodium methanearsonate at 100 g/g was a function of organic matter addition and moisture conditions. Loss of (74)As was greatest from soils that received an exogenous carbon source and were maintained under wet conditions. Arsenic-74 sorbed by soils of pH 4,6, and 8 was fractionated by a differential dissolution precedure commonly used for phosphorus. Iron arsenate (soluble in 0.1N NaOH) was the most abundant form followed by aluminum arsenate (soluble in 0.5N NH4F). The soils generally contained more aluminum arsenate at pH 4 than at pH 6 or 8. Calcium arsenate fractions (soluble in 0.5N N2SO4) were usually higher at pH 6 and 8 than at pH 4. Water-soluble forms and nonextractable forms were inversely proportional to each other.

76:05B-021
DISSOLVED NUTRIENT LOSSES IN STORM RUNOFF FROM FIVE SOUTHERN PINE WATERSHEDS,
Schreiber, J.D., Duffy, P.D., and McClurkin, D.C.
Agricultural Research Service, Sedimentation Research Laboratory, Oxford, Mississippi.
Journal of Environmental Qualtiy, Vol. 5, No. 2, p 201-205, 2 fig, 6 tab, 21 ref.
(See 76:02E-001)

76:05B-022
EFFECT OF ATMOSPHERIC STABILITY ON WATER TEMPERATURE PREDICTIONS FOR A THERMALLY LOADED STREAM,
DeWalle, D.R.
Pennsylvania State University, School of Forest, University Park, Pennsylvania.
Water Resources Research, Vol. 12, No. 2, p 239-244, April 1976. 3 fig, 2 tab, 19 ref. OWRT C-4199(No. 9032)(2).

Descriptors: *Model studies, *Energy budget, *Water temperature, *Heat transfer, *Discharge(Water), Air-water interfaces, Air temperature, Humidity, Wind velocity, Radiation, Equations, Pennsylvania, Atmosphere, *Thermal pollution.

A steady state one-dimensional energy budget equation was numerically integrated to predict water temperatures in a 5.45-km-long thermally loaded stream reach for 131 five- or six-hour periods. Downstream water temperature prediction errors (measured minus predicted) using Jobson's Lake Hefner evaporation equation averaged -2.11 C and were well correlated (R2 = 46%) with an index to atmospheric stability. Use of a modified form of Shulyakovskiy's evaporation equation, which includes a term for evaporation by free convection, significantly reduced the average prediction error to 0.89 C and eliminated the effects of atmospheric stability (R2 less than 1%). Correction of wind velocity data for the velocity of the air relative to the stream velocity also reduced prediction errors.

76:05B-023
PULSED DISPERSION OF TRACE CHEMICAL CONCENTRATIONS IN A SATURATED SORBING POROUS MEDIUM,
Lindstrom, F.T.
Oregon State University, Department of Statistics, and Department of Mathematics, Corvallis, Oregon.
Water Resources Research, Vol. 12, No. 2, p 229-238, April 1976. 5 fig, 22 ref. PHS ES-00040.

Descriptors: *Dispersion, *Mathematical models, *Distribution patterns, Saturated flow, Sorption, Porous media, Equations, Soil water, Theoretical analysis, Graphical analysis, Computers, Water chemistry, Trace elements, Mass transfer, Laplaces equation, *Path of pollutants.

A rather simple, yet complete, mathematical model for the pulsed dispersion of trace chemical concentrations in a water-saturated sorbing porous medium was stated, and the resulting integrodifferential equation of transport was solved via Laplace transform methods. A typical example of a soil water dispersion system was discussed with the aid of free and sorbed phase concentration distribution curves.

76:05B-024
NUMERICAL SIMULATION OF WASTE MOVEMENT IN STEADY GROUNDWATER FLOW SYSTEMS,
Pickens, J.F., and Lennox, W.C.
Waterloo University, Department of Earth Sciences, Ontario, Canada.
Water Resources Research, Vol. 12, No. 2, p 171-180, April 1976. 10 fig, 1 tab, 24 ref.

Descriptors: *Model studies, *Groundwater movement, *Underground waste disposal, Groundwater, Waste disposal, Water pollution, Water pollution sources, *Path of pollutants, Mathematical models, Finite element analysis, Analytical techniques, Wastes, Waste disposal wells, Flow, Flow system, Water table, Infiltration.

The finite element method based on a Galerkin technique was used to formulate the problem of simulating the two-dimensional transient movement of conservative or nonconservative wastes in a steady state saturated groundwater flow system. The convection-dispersion equation was solved in two ways: in the conventional Cartesian coordinate system and in a transformed coordinate system equivalent to the orthogonal curvilinear coordinate system of streamlines and normals to those lines. The two formulations produced identical results. A sensitivity analysis on the dispersion parameter "dispersivity" was performed, establishing its importance in convection-dispersion problems. Examples involving the movement of nonconservative contaminants described by distribution coefficients and samples with variable tribution coefficients and examples with variable input concentration were also given. The model can be applied to environmental problems related to groundwater contamination from waste disposal sites.

76:05B-025
A FINITE ELEMENT MODEL OF CONTAMINANT MOVEMENT IN GROUNDWATER,
Cabrera, G. and Marino, M.A.
Chile University, Centro de Recursos Hidraulicos, Santiago, Chile.
Water Resources Bulletin, Vol. 12, No. 2, p 317-335, April 1976. 9 fig, 17 ref.

Descriptors: *Model studies, Wastes, *Groundwater movement, Mathematical models, Computer models, *Finite element analysis, Pollutants, *Path of pollutants, Groundwater, Aquifers, Streams, Recharge, Groundwater recharge, Infiltration, Flow, Surface-groundwater relationships, Subsurface flow, Subsurface waters.

Transient, two-dimensional solutions were developed which describe the movement and distribution of a conservative substance in a stream-aquifer system. The solutions were obtained by solving sequentially the groundwater flow and mass transport equations. A variational approach in conjunction with the finite element method was used to solve the groundwater flow equation. Galerkin's approach coupled with the finite element method was used to solve the mass transport equation. Linear approximated triangular elements and a centered scheme of numerical integration were employed to calculate the hydraulic head distribution and the concentration of solute in the flow region. The linear approximation used to define the concentration function within each element is not appropriate for cases involving steep concentration gradients. For such cases, higher order approximations are necessary to assure the continuity of gradients across interelemental boundaries. Numerical examples that illustrate the applicability of the model were presented.

76:05B-026
AN ANALYSIS OF THE NUMERICAL SOLUTION OF THE TRANSPORT EQUATION,
Gray, W.G., and Pinder, G.F.
Princeton University, Department of Civil Engineering, Princeton, New Jersey.
Water Resources Research, Vol. 12, No. 3, p 547-555, June 1976. 8 fig, 1 tab, 5 ref. NSF-AER74-01765.

Descriptors: *Mass transfer, *Dispersion, *Finite element analysis, *Numerical analysis, *Fourier analysis, Waves (Water), Convection, Computers, Equations, Mathemeical studies, *Path of pollutants.

The relative merits of numerical procedures used for the solution of the convective dispersive mass transport equation were examined in terms of frontal smearing and concentration overshoot. The testing for assessing the relative accuracy of some selected numerical procedures was based on a Fourier series representation of the solution to the governing equation and its discretized counterpart. Through a comparative examination of the analytically and numerically computed amplitude and speed of the Fourier components, the dispersive and dissipative properties of a numerical scheme were easily analyzed. The analysis indicated that the commonly observed phenomenon of overshoot of a concentration pulse was due to the inability of the numerical schemes to propagage the small wavelengths which are important to the description of the front. The numerical smearing of a sharp front was due to dissipation of these small wavelengths. The finite element method was found to be superior to finite difference methods for solution of the convective-dispersive equation.

76:05B-027
ANALYTICAL THREE-DIMENSIONAL TRANSIENT MODELING OF EFFLUENT DISCHARGES,
Yeh, G.T., and Tsai, Y.J.
Stone and Webster Engineering Corporation, Boston, Massachusetts.
Water Resources Research, Vol. 12, No. 3, p 533-540, June 1976. 10 fig, 19 ref.

Descriptors: *Unsteady flow, *Dye releases, *Dye concentration, *Effluents, *Analytical techniques, *Turbulent flow, *Hudson River, *Mathematical models, Thermal pollution, Diffusion, Buoyancy, Density currents, Tidal waters, Equations, Pollutant identification, *Path of pollutants.

A transient, three-dimensional turbulent diffusion equation describing the concentration distribution of a substance or heat in a time-dependent flow field was solved analytically. Two models were considered: one treated both the depth and the width of a water body as being finite, while the other dealt with finite depth but with infinite width. In the search for solutions, the method of Green's function was utilized to the optimum advantage. The solutions were developed for cases in which the velocity field can be described as any integratable function of time. For practical applications, the velocity was assumed to be the sum of a constant and a harmonic component. There were no limitations on the type of source conditions. Results were compared with field measurements and showed the models to be capable of simulating the dye distribution in tidal water bodies. The models should provide the engineering community with a quick and easy way of predicting the distribution of effluent discharges. They should obviate the need of using tedious and time-consuming numerical models, as occasions often arise in which such complicated models may not be warranted.

76:05B-028
DESCRIBING VARIANCE WITH A SIMPLE WATER QUALITY MODEL AND HYPOTHETICAL SAMPLING PROGRAMS,
Moore, S.F., Dandy, G.C., and DeLucia, R.J.
Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, Massachusetts.
Water Resources Research, Vol. 12, No. 4, p 795-804, August 1976. 7 fig, 2 tab, 18 ref.

Descriptors: *Water quality control, *Sampling, *Decision making, Evaluation, Time, History, Data collections, Estimating, Mathematical models, Simulation analysis, Costs, Impoundments, Eutrophication, Equations, Systems analysis, *Risks.

An explicit treatment of the uncertainty in the state of water quality in a body of water can provide a quantitative basis for sampling decisions. Filtering theory, an extension of Bayesian analysis to dynamic systems, is used to obtain an algorithm which describes the time history of variance (uncertainty) in estimates of water quality parameters. Uncertainties arising from measurement errors, incompleteness of data, and random fluctuations exhibited by natural phenomena are taken into account. Sampling design capabilities are illustrated in an evaluation of sampling frequencies for the National Eutrophication Survey. The adequacy of any sampling program is dependent on the available prior data and on the value associate with reductions in uncertainty.

76:05B-029
OPTIMAL ESTIMATION OF DO, BOD, AND STREAM PARAMETERS USING A DYNAMIC DISCRETE TIME MODEL,
Koivo, A.J., and Phillips, G.
Purdue University, Department of Electrical Engineering, Lafayette, Indiana.
Water Resources Research, Vol. 12, No. 4, p 705-711, August 1976. 9 fig, 10 ref.

Descriptors: *Path of pollutants, *Model studies, *Optimization, *Biochemical oxygen demand, *Dissolved oxygen, *Streams, *Mathematical models, Computer models, Dynamic programming, Organic matter, Water quality, Water pollution, Pollutants, Reaeration, Self-purification, Waste assimilative capacity, Equations, Mathematical studies.

A modified Streeter-Phelps equation was used as the starting equation to obtain a discrete time mathematical representation which represents a model for the biological oxygen demand and the dissolved oxygen concentrations in a polluted stream. The unknown parameters to be estimated were treated as state variables in order to compute their numerical values from noise-corrupted measurements. An optimal estimator was constructed for the estimation of the unknown parameters. The optimization scheme can be implemented in a small computer. The approach was illustrated by a numerical example.

76:05B-030
SIMILARITY OF THE MEAN MOTION OF FLUID PARTICLES DISPERSING IN A NATURAL CHANNEL,
Day, T.J., and Wood, I.R.
Geological Survey of Canada, Ottawa, Ontario, Canada.
Water Resources Research, Vol. 12, No. 4, p 655-666, August 1976. 13 fig, 3 tab, 22 ref.

Descriptors: *Dispersion, *Flow, *Turbulence, *Channel morphology, *Hydrologic data, Velocity, Methodology, Tracers, Distribution patterns, Statistical methods.

The longitudinal dispersion in natural river channels was shown to exhibit the characteristics,constant velocity ratios, and similarity in the distribution of physical dimensions of a self-similar process. Although the kinematic relations and the structure of the turbulent field were sensitive to the nature of the flow boundaries and the geometry of the channel, similarity was maintained in flows in a wide range of steep gravel and boulder bed channels. A simple method was developed for predicting the longitudinal pattern of dispersion. It contained three basin hydraulic parameters which could be determined by a field experiment. Data on steep channels and distances up to 1000 channel widths from the dump point were used in developing the method. Though these data were rather limited in scope, the results suggested that the general method may be applicable to streams with a range of characteristics.

76:05B-031
MODELING OF UNSTEADY TEMPERATURE DISTRIBUTION IN RIVERS WITH THERMAL DISCHARGES,
Hills, R.G., and Viskanta, R.
Purdue University, School of Mechanical Engineering, and Heat Transfer Laboratory, Lafayette, Indiana.
Water Resources Research, Vol. 12, No. 4, p 712-722, August 1976. 20 fig, 29 ref.

Descriptors: *Heated water, *Thermal stratification, Analytical techniques, *Turbulent flow, *Mixing, Water temperature, Channel flow, Heat transfer, Radiation, Numerical analysis, Equations, Rivers, *Thermal pollution.

Unsteady temperature distribution was analyzed in a wide channel simulating a river. The effects of thermal discharges, meteorological conditions, solar and atmospheric radiation, and channel parameters on the thermal structure of a river were analyzed and discussed by utilizing an analytical model for the unsteady three-dimensional temperature distribution in the far field of a thermally stratified channel. The conservation of energy equation for turbulent flow was solved numerically with an alternating direction implicit finite difference scheme. The effects of thermal start-up, discharge temperature level, discharge location, river flow velocity, and other factors were investigated. The results showed that the greater the temperature excess above the ambient at the discharge, the greater downstream distance is needed to reach a fully mixed condition because of the suppressive effect of stratification on the turbulent mixing. The greater surface temperatures associated with thermally stratified flow resulted in increased heat dissipation and water evaporation from the surface.

76:05B-032
NITRATE AND CHLORIDE POLLUTION OF AQUIFERS: A REGIONAL STUDY WITH THE AID OF A SINGLE-CELL MODEL,
Mercado, A.
Tahal-Water Planning for Israel, Limited, Tel-Aviv, Israel.
Water Resources Research, Vol. 12, No. 4, p 731-747, August 1976. 15 fig,

6 tab, 7 ref.

Descriptors: *Nitrates, *Chlorides, *Water pollution, *Aquifers, *Mathematical models, Water pollution sources, Hydrologic properties, Zone of aeration, Water wells, Water table, Biochemistry, Groundwater, Tracers, Forecasting, Monte Carlo method, Probability, Statistical models, Tertiary treatment, Groundwater recharge, Equations.

A single-cell model was used to study the regional chloride and nitrate pollution patterns in part fo the coastal aquifer of Israel. The model integrated pollution sources on the land surface, hydrologic parameters of the aquifer and the unsaturated zone, and variations of chloride and nitrate concentration distribution in pumping wells. Complicated hydrologic and biochemical processed in the unsaturated zone were simplified and represented by two basic parameters: (1) transit time from land surface to the aquifer, and (2) nitrogen losses in the soil. It was shown that linear relationships exist between nitrogen quantities released on the surface and the quantities reaching the water table. The calibration of the model enabled its use for prediction purposes. The Monte Carlo technique was introduced to determine the range of predicted average groundwater concentrations as a function of time. The forecasts presented call for urgent protection measures in order to meet drinking water standards for maximum nitrate concentrations. Thirteen alternative protection measures were examined and then compared to predictions based on present nitrogen loads and hydrologic regime. The exchange relationships between these measures were derived, and it was suggested that they can be used later for evaluating economic criteria for protecting groundwater quality.

76:05B-033
DISPERSION OF WATER POLLUTANTS IN A TURBULENT SHEAR FLOW,
Yeh, G.T., and Tsai, Y-J.
Stone and Webster Engineering Corporation, Boston, Massachusetts.
Water Resources Research, Vol. 12, No. 6, p 1265-1270, December 1976. 4 fig, 14 ref.

Descriptors: *Dispersion, *Pollutants, *Turbulent flow, *Model studies, Mathematical models, Water quality, Rivers, Streams, Velocity, Diffusivity, Flow, Streamflow, Analytical techniques, Water pollution sources, *Path of pollutants.

A steady-state, two dimensional turbulent diffusion equation discribing the concentration distribution of a substance from a line source in a shear flow field was solved analytically. A similar formulation may be developed for any other kinds of sources. In the study, the velocity and eddy diffusivity were assumed to be variables given by the power law approximations, and the depth of the water body was assumed finite, with no-flux boundary conditions applied at the water surface and bottom. This represents a first step toward analytical water quality modeling, which realistically includes the effects of both the finiteness in water depth and the nonhomogeneity in velocity and diffusivity. Results from the present model were compared with those obtained from the finite depth constant coefficient model and from the infinite depth constant coefficient model. They showed significant and realistic differences in the prediction of concentration patterns. The effects of nonhomogeneous velocity and diffusivity are cancelled out by the effect of boundary reflection far away from the source.

76:05B-034
COMPUTER SIMULATION OF PHOSPHORUS MOVEMENT THROUGH SOILS,
Harter, R.D., and Foster, B.B.
New Hampshire University, Institute of Natural and Environmental Resources, Durham, New Hampshire.
Soil Science Society of America Journal, Vol. 40, No. 2, p 239-242, March-April 1976. 4 fig, 1 tab, 9 ref.

Descriptors: Computer models, Model studies, Phosphorus, Soil investigations, Mathematical models, Waste water, Nutrients, Fertilization.

Although the movement of P through soil can be described by mathematical models, this approach has certain limitations in practical application, particularly when soil is used for waste water renovation. To circumvent the limitations of mathematical modeling, empirical adsorption equations can be obtained and utilized in computer simulation of phosphorus movement. In this way, the renovation lifetime of a soil can be estimated. This approach is not limited to P, and can be used for any potential ground-water contaminate, whether inorganic or organic.

76:05B-035
AGRICULTURAL RUNOFF, A BIBLIOGRAPHY, VOLUME 2
Office of Water Research and Technology,
Washington, D.C.
Water Resources Scientific Information Center, Report OWRT/WRSIC 76-203,
July 1976, 286 p.

Descriptors: *Agricultural runoff, *Bibliographies, *Farm wastes, *Feed lots, Waste disposal, Waste treatment, Water pollution sources, Water pollution control, Runoff, Path of pollutants.

This report, containing 187 abstracts, is another in a series of planned bibliographies in water resources produced from the information base comprising SELECTED WATER RESOURCES ABSTRACTS (SWRA). At the time of search for this bibliography, the data base had 95,781 abstracts covering SWRA through April 15, 1976 (Volume 9, Number 8). Author and subject indexes are included. The first volume (see W72-05840) was issued in January 1972 and covered the material announced in SWRA from October 1968 through December 1971. This volume covers the period from January 1972 through April 1976.

76:05B-036
SUBSURFACE BRINE DISPOSAL - BE REASONABLE,
Fryberger, J.S.
Engineering Enterprises, Inc., Norman, Oklahoma.
Ground Water, Vol. 14, No. 3, p 150-156, May-June 1976. 5 fig, 11 ref.

Descriptors: *Brine disposal, *Groundwater, *Hydrogeology, *Oklahoma, Oil wells, Oil wastes, Injection wells, Brines, Waste disposal, Wastes, Pollutants, Aquifers, Piezometry, Potentiometric level, Geology, Legal aspects, Oil industry, Agriculture, Irrigation.

A classic battle between landowners desireing to protect their fresh groundwater from possution and oil companies needing a disposal zone for injection of oil-field brines developed in Texas County, Oklahoma. Initial studies showed that the disposal zone (Glorieta Formation) was in placed only 500 feet below the bottom of the fresh-water aquifer (Ogallala Formation). Solution/collapse features in the intervening formations plus numerous poorly plugged wells and exploration holes provided potential avenues of brine migration. The potential for pollution appeared very real. The landowners not only wanted to halt construction of new brine disposal wells, but also wanted all 33 existing disposal wells abandoned and plugged. Tempers flared and intermittent litigation continued for over two years. A more complete hydrogeologic analysis led to the following observations: (1) the potentiometric surface in the Glorieta is 100 to 400 feet below the water table in the Ogallala in areas where brine disposal is taking place; and (2) the transmissivities of the Glorieta and disposal rates are such that even pressure gradients around disposal wells are below the water level in the Ogallala. These hydrologic facts led to the conclusion that, even with a perfectly open conduit connecting the two formations, migration of disposal brine from the Glorieta into the fresh-water Ogallala would be impossible in the critical area because of pressure relationships.

76:05B-037
PREDICTION OF FUTURE NITRATE CONCENTRATIONS IN GROUND WATER,
Young, C.P., Oakes, D.B., and Wilkinson, W.B.
Water Research Centre, Medmenham Laboratory, Marlow (England).
Ground Water, Vol. 14, No. 6, p 426-438, November-December 1976. 20 fig, 3 tab, 29 ref.

Descriptors: *Nitrates, *Groundwater, *Forecasting, Surveys, On-site investigations, Model studies, Mathematical models, Aquifers, Foreign countries, Sandstones, Foreign projects, Nitrogen, Chlorides, Tritium, Fertilizers, Wells, Water wells, Land use, Effects, Agriculture, Water pollution, Pollutants.

Over the last few years, rises in the nitrate content of groundwater from wells and springs in the principal aquifers of the United Kingdom have been observed. In a number of cases, the concentrations have exceeded the WHO lower recommended limit. In order to determine the reason for the rise, to assess whether it will continue, and to ascertain the eventual nitrate levels, the Water Research Centre undertook an extensive program of drilling and sampling on the Chalk and Bunter Sandstone. By August 1976, 22 sites had been examined. This work established that high nitrate concentrations (peaks up to 60 mg/l NO_3-N have been observed) are present in the unsaturated aquifers at fertilized arable/ley sites. At unfertilized grassland sites, nitrate concentrations are low (less than 4 mg/l NO_3-N), and they are below fertilized established grassland values, which are in the intermediate range. At one farm site near Winchester, models to predict the rate of movement of nitrate through the unsaturated and saturated Chalk were developed. These models suggest that the nitrate levels at this site will remain at an essentially constant value of about 4 mg/l NO_3-N until the late 1970's, when they will rise progressively to about 14 mg/l NO_3-N. The models were checked against tritium data, and the approach is now being extended to other sites.

76:05B-038
WASTEWATERS IN THE VADOSE ZONE OF ARID REGIONS: GEOCHEMICAL INTERACTIONS,
Runnells, D.D.
Colorado University, Department of Geological Sciences, Boulder, Colorado.
Ground Water, Vol. 14, No. 6, p 374-385, November-December 1976. 3 fig, 3 tab, 33 ref.

Descriptors: *Waste water disposal, *Arid lands, *Vadose water, *New Mexico, Geochemistry, Chemical reactions, Leachate, Waste water treatment, Waste dilution, Hydrogen ion concentration, Chemical precipitation, Hydrolysis, Oxidation, Reduction (Chemical), Filtration, Membrane processes, Sorption.

Because of increasingly stringent laws governing discharge of fluid wastes to surface waters, the alternative of discharge to the subsurface has become attractive. The physical-chemical processes that prevail in the subsurface are not well understood, but they are clearly not identical to processes of purification in surface waters. Eleven physical-chemical processes can be identified as having potential value for purifying wastes discharged to the subsurface, as follows: dilution, buffering of pH, precipitation by reaction, hydrolysis oxidation or reduction, filtration, volatilization, biological assimilation, radioactive decay, membrane filtration, and sorption. Discharge to the vadose zone may be a safe means of disposal of wastes in arid regions. But it is necessary to carefully test the suitability of a particular site for a particular waste. Regulations governing subsurface discharge should take into account the physical-chemical processes that may act to purify the waste fluids. In one set of experiments, a soil from Sulfur Springs, New Mexico, was capable of removing large quantities of dissolved molybdenum and copper from a synthetic mill water, and the soil was able to quantitatively retain the copper during subsequent leaching by fresh and metal-free mill waters.

76:05B-039
MONITORING CYCLIC FLUCTUATIONS IN GROUND-WATER QUALITY,
Pettyjohn, W. A.
Ohio State University, Department of Geology and Mineralogy, Columbus, Ohio.
Ground Water, Vol. 14, No. 6, p 472-480, November-December 1976. 9 fig, 13 ref

Descriptors: *Water quality, *Groundwater, *Groundwater recharge, *Water pollution, Monitoring, Sampling, Wells, Water wells, Path of pollutants, Chlorides, Brines, Oil fields, Rainfall, Precipitation (Atmospheric), Aquifers, Pollution, Fluctuations, Pollutants.

The chemical quality of water in many shallow and surficial aquifers exhibits cyclic fluctuations. These fluctuations are caused by the intermittent flushing of contaminants into the ground during recharge events. The contaminants may be natural or reflect man's activities, particularly waste disposal schemes. Over the past 12 years, an oil field, brine-contaminated aquifer in central Ohio has been monitored. Data from three closely spaced wells tapping selected parts of the aquifer indicated that brine is flushed into the ground during recharge events, and that each contaminated mass maintains much of its integrity as it sinks to the bottom of the aquifer and then migrates laterally to the adjacent river. The most concentrated mass that covers the largest area infiltrates during the spring recharge period, but less concentrated and smaller masses may occur any time rainfall is sufficient to overcome the soil moisture deficiency. Because of the cyclic nature of recontamination events, care and common sense must be exercised in the extrapolation of quality data, particularly in regard to estimation of contaminant flushing rates.

76:05B-040
NONPOINT SOURCE POLLUTION FROM AGRICULTURAL RUNOFF,
Haith, D.A., and J.V. Dougherty
New York State College of Agriculture and Life Sciences, Department of Agricultural Engineering, Ithaca, New York.
Journal of the Environmental Engineering Division, American Society of Civil Engineers, Vol. 102, No. EE5, Proceedings Paper 12481, p 1055-1069, October 1976. 1 fig, 7 tab, 39 ref, 2 append. OWRT B-030-NY(3).

Descriptors: *Water pollution sources, *Water quality, *Agricultural runoff, *New York, Nitrogen, Phosphorus, Water pollution, Model studies, Watersheds (Basins), Nutrients, Storm runoff, Surface waters, Estimating, Forecasting, Agriculture, Agricultural watersheds, Farm wastes.

An operational procedure was developed which is suitable for estimating nonpoint source water pollution due to runoff from agricultural land and is sensitive to regional variations in weather, soils, and crop management. Runoff was estimated using the Soil Conservation Service's semi-empirical runoff equation. Although not presently applicable to snowmelt runoff, the procedure could be extended to winter runoff by use of suitable estimating methods. Nitrogen and phosphorus in agricultural runoff were estimated for a five-watershed area totalling 578 sq km in Broome and Tioga Counties, New York, for the years 1971 and 1972. Comparison was made with two other estimates which were obtained using areal loading factors (losses of nutrients per unit area). Although the three different estimates were of comparable orders of magnitude, the loading factor estimates were not sensitive to the soils, weather, or crop distributions of the study region and may overestimate losses of nitrogen in agricultural runoff.

76:05B-041
GEOELECTRIC SOUNDING FOR DELINEATING GROUND-WATER CONTAMINATION,
Kelley, W.E.
Rhode Island University, Department of Civil and Environmental Engineering, Kingston, Rhode Island.
Ground Water, Vol. 14, No. 1, p 6-10, January-February 1976. 7 fig, 12 ref.

Descriptors: *Resistivity, *Water pollution, *Landfills, *Rhode Island, Conductivity, Groundwater, Glacial aquifers, Water quality, Path of pollutants, Monitoring.

A resistivity survey was made in the vicinity of a landfill in a glacial aquifer to determine the extent of groundwater contamination. An examination of the sounding curves and logs of nearby test borings suggested a three-layer geoelectric model for studying water quality variations. The thicknesses and the resistivities of the upper two layers were fixed. Differences in apparent resistivity were assumed to be due only to differences in specific conductance of groundwater in the saturated zone (third-layer resistivities). Apparent resistivities at the largest probe spacing, 102 feet, were then computed for a range of assumed third-layer resistivities. Specific conductances corresponding to third-layer resistivities were then computed using an assumed formation factor of 4.5. A relation between apparent resistivity at the 102-ft spacing and specific conductance was developed for converting apparent resistivities to specific conductances. Quadratic trend surfaces developed for specific conductances measured at monitoring wells and computed from apparent resistivity were shown to be in good agreement. Under favorable conditions, interpretation of electrical sounding curves provides a basis for estimating specific resistivity methods. This leads to a quantitative assessment of groundwater contamination which compares favorably with that determined from monitoring wells.

76:05B-042
THE MODELLING AND CONTROL OF POLLUTION IN A RIVER SYSTEM,
Young, P., Beck, B., and Singh, M.
Cambridge University, Department of Engineering, (England).
Journal of Hydrology, Vol. 28, No. 2/4, p 289-316, February 1976. (Published in Amsterdam). 7 fig, 24 ref.

Descriptors: *Water pollution control, *Mathematical models, *River systems, *Water quality, Dissolved oxygen, Biochemical oxygen demand, Effluents, Sewage, Design, Simulation analysis, Optimization, Equations, Systems analysis, Path of pollutants.

A river which is being used either as a source for potable supply or for recreation requires an adequate and, if possible, an automatic control system for maintaining pollution levels within reasonable bounds consistent both with the needs of the community and the requirements for maintaining a satisfactory ecological balance. This paper makes a preliminary examination of the design of such a system by considering the dynamic modeling and control of dissolved oxygen (DO) and biochemical oxygen demand (BOD) in a river system. This includes a discussion on the derivation and verification of simple DO-BOD models for a typical river, as well as initial thoughts on the operational control of sewage effluent discharges in order to maintain specified levels of dissolved oxygen in single and multiple reach river systems.

76:05B-043
FLUVIC ACID AND AQUATIC MANGANESE TRANSPORT,
Zajicek, O.T. and Pojasek, R.B.
Massachusetts University, Department of Chemistry, Amherst, Massachusetts 01002
Water Resources Reaseach, Vol. 12, No. 2, p 305-308, April 1976. 2 fig, 3 tab, 30 ref.

Descriptors: Manganese, Return flow, Water quality, Rivers, Water resources, Organic compounds.

The role of allochthonous organic substances in the solubilization of manganese was investigated. The organic substances used were leachates of a variety of watershed materials, fluvic acid, and a number of pure model compounds. It was found that manganese concentration and water color were directly proportional, in most cases, and that the organic materials comprising the color are effect in dissolving manganese oxides and stabilizing the dissolved manganese in solution.

76:05B-044
CHLORIDE ACCUMULATION NEAR CORN ROOTS UNDER DIFFERENT TRANSPIRATION, SOIL MOISTURE, AND SOIL SALINITY REGIMES,
Sinha, B.K. and Singh, N.T.
Punjab Agricultural University, Department of Agricultural Engineering, Ludhiana, Punjab, India
Agronomy Journal, Vol. 68, No. 2, p 346-348, March-April 1976. 3 tab, 8 ref.

Descriptors: Corn, Chloride, Soil water, Soil moisture, Saline soil, Salinity, Transpiration, Root zone, Root systems, Root development.

The magnitude of 36Cl accumulation around roots of corn plants exposed to low, medium, and high transpiration rates was studied in laboratory experiments using Tulewal loamy sand salinized to ECe of 3 and 6 mmhos/cm with sodium chloride. Radioautographs and quantitative measurements of 36Cl in high transpiration treatment showed the highest concentration of the element in regions closest to the root. At high transpiration rates the chloride content of the soil close to the roots increased while the same soil showed a decrease in the chloride content when the plants were exposed to low transpiration treatment. Chloride concentrations in the 'apparent free space' and soil close to the roots was two to three times that in the bulk soil, depending upon the amount of water transpired/unit root length. At higher transpiration rates, salt accumulation increased with greater soil moisture content but was either unaffected or decreased closer to the root-soil interface, when the transpiration rate was low. The results indicate that the salinity tolerance limits of plants would be greatly influenced by the prevailing evaporative demand.

76:05B-045
LEACHING OF PHOSPHATE AND SELECTED CATIONS FROM SANDY SOILS AS AFFECTED BY LIME,
Chaiwanakupt, P. and Robertson, W.K.
Thai Ministry of Agriculture, Agricultural Chemistry Division, Bankok, Thailand
Agronomy Journal, Vol. 68, No. 3, p 507-511, May-June 1976. 12 fig, 2 tab, 7 ref.

Descriptors: Phosphorus, Phosphate, Leaching, Cations, Sandy soil, Lime, Groundwater, Soil investigations.

It is important to determine if and to what extent P moves through some acid sandy soils and, in view of the high cost of fertilizer P and the problems associated with pollution of groundwater, what can be done to prevent or reduce the movement when it occurs. Segmented columns, 25 cm in length and 5 cm in diam., were used to study P leaching in five mineral and one organic soil. A total of 25 or 50 cm H20 was passed through the columns, containing soil from various depths, after treatment in the top 2 cm with 0 to 600 ppm P tagged with 32P. Leaching of K, Ca, and Mg occurred in all soils. The amount was generally related to the CEC or the levels present in the extractable form before the leaching began. Leaching of Fe and Al was determined only on soils where P leaching was appreciable. These ions generally leached with P but there was a direct relationship between leached and 0.1 N HCl extractable ions. These data are of value in evaluating and determining P and lime requirements.

76:05B-046
SOIL NITRATE LOSS DURING IRRIGATION: ENHANCEMENT BY PLANT ROOTS,
Volz, M.G., Ardakani, M.S., Schulz, R.K., Stolzy, L.H. and McLaren, A.D.
Connecticut Agricultural Experiment Station, Department of Plant Physiology, New Haven, Connecticut 05604.

Descriptors: Nitrate, Leaching, Irrigation, Irrigation effects, Root development, Barley, Denitrification, Organic matter.

Since roots can both absorb NO-3 and supply organic matter for NO-3 reduction by soil microbes, the influence of a root system on No-3-N loss from soil solution during irrigation was studied. Two Hanford sandy loam plots, one fallow, and the other planted to CM-67 barley, were ponded for 44 hours with a solution containing 100 ppm N and 46 ppm Cl- as KNO3 and CaCl(2), respectively. Nitrate--N, NO-2-N, NH(+)4-N, and Cl- concentrations in soil solution were determined and related to N uptake by roots and microbial transformation of NO-3.

76:05B-047
NUTRIENT MOVEMENT IN STREAMFLOW FROM AGRICULTURAL WATERSHEDS IN THE GEORGIA COASTAL PLAIN,
Asmussen, L.E., Sheridan, J.M., and Booram, C.V. Jr.
Agricultural Research Service, United State Department of Agriculture, Southern Region, Southeast Watershed Research Unit, Tifton, Georgia
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 28 p, 12 fig, 3 tab, 7 ref.

Descriptors: Nitrates, Nitrite, Runoff, Watersheds, Return flow, Georgia, Stream flow.

As baseline information on nonpoint pollution, the monitoring of nitrogen, phosphates and chloride was begun in 1974 at 9 locations within a predominately agricultural Upper Coastal Plain watershed (311 to 32,751 ha) at Tifton, Georgia. Stream flow was continuously measured at all sites. Chemical load is computed for one continuously sampled site, and seasonal relationships are noted.

76:05B-048
CONCEPTS IN THE CONTROL OF NONPOINT WATER POLLUTION,
Frere, M.H., Woolhiser, D.A., Caro, J.H., Stewart, B.A., Wischmeier, W.H.
United States Department of Agriculture, Agricultural Research Service, Chickasha, Oklahoma.
Presented at the National Water Resources and Ocean Engineering Convention of the American Society of Civil Engineers, April 5-8, 1976, San Diego, California, 24 p, 8 fig, 2 tab, 11 ref.

Descriptors: Sediments, Salt salinity, Saline water, Saline soils, Nutrients, Fertilization, Pesticides, Return flow.

Sediment, salt, nutrients, and pesticides are the principal types of pollutants from nonpoint sources. Pollution from nonpoint sources is very difficult to identify and monitor. While standards have been established for municipal, industrial, and agricultural uses of water, adequate standards have not yet been developed to protect our environment. The lack of standards makes it very difficult to judge the adequacy of any control program. In developing a control program there are some methods that can be used over a broad area. These include education, incentive, taxation, or legal penalties. All have good and bad points. Many of the practices that must be used to control pollution are site specific; that is, the practice must be designed for a specific field. In some cases, a practice may solve one problem but create another. ARS has developed a set of flow charts to assist land planners in selecting practices for croplands. These charts should cause the user to recognize the possible pollution sources and to evaluate the consequences of any practices selected to control these sources. Similar flow charts could be developed for other land uses.

76:05B-049
QUALITY MONITORING OF IRRIGATION WATER AND RETURN FLOWS IRRIGATION SEASON 1974,
Guitjens, J.C., Hamannah, C.N., and Miller, W.W.
Nevada University, Max C. Fleischmann College of Agriculture, Reno, Nevada.
Publication No. R114, July 1976. 81 p, 36 fig, 19 tab, 42 ref, 8 append.

Descriptors: Irrigation water, Return flow, Irrigation practices, Irrigation effects, Tailwater, Water quality, Sampling.

Quantitive and qualitative measurements of irrigation applications (head water) to and return flow (tail water) from selected fields were made at the Saram, Heritage and Witt Ranches in the Carson Valley. Totalizing flow meters were used to to measure quantity of irrigation water application as well as the quantity of surface return flow (tail water) at each site. Water quality samples were taken at each of these metering points at 12-hour intervals and analyzed for temperature, dissolved oxygen, biochemical oxygen demand, ortho-phosphate, nitrate-nitrogen, turbidity, electrical conductivity, pH, calcium + magnesium, sodium, bicarbonate, chloride, and sulfate.

76:05B-050
MODELING PESTICIDES AND NUTRIENTS ON AGRICULTURAL LANDS,
Donigian, A.S., Jr., and Crawford, N.H.
Hydrocomp, Incorporated, Palo Alto, California 94304
Environmental Protection Agency Report No. 600-2-76-043, February, 1976.

Descriptors: Simulation, Runoff, Hydrology, Soil erosion, Nitrogen, Phosphorus, Snowmelt, Watersheds, Pesticides, Return flow, Nutrients, Model studies.

Modifications, testing, and further development of the Pesticide Transport and Runoff (PTR) Model have produced the Agricultural Runoff Management (ARM) Model.

The ARM Model simulates runoff, snow accumulation and melt, sediment loss, pesticide soil interactions, and soil nutrient transformations on small agricultural watersheds. The report discusses the major modifications to and differences between the PTR and AEM Models. An energy-balance method of snow simulation, and a first-order transformation approach to nutrient modeling are included. Due to lack of data, the nutrient model was not tested with observed data; testing and refinement are expected to begin in the near future. Instrumented watersheds in Georgia provided data for testing and refinement of the runoff, sediment and pesticide portions of the ARM Model. Comparison of simulated and recorded values indicated good agreement for runoff and sediment loss, and fair to good agreement for pesticide loss. Pesticides transported only by sediment particles were simulated considerably better than pesticides that move both in solution and on sediment. A sensitivity analysis of the ARM Model parameters demonstrated that soil moisture and infiltration, land surface sediment transport, pesticide-soil interactions, and pesticide degradation are the critical mechanisms in simulating pesticide loss from agricultural watersheds.

76:05B-051
LOADING FUNCTIONS FOR ASSESSMENT OF WATER POLLUTION FROM NONPOINT SOURCES,
McElroy, A.D., Chiu, S.Y., Nebfen, J.W., Aleti, A., and Bennett, F.W.
Midwest Research Institute, Kansas City, Missouri 64110
Environmental Protection Agency Report No. 600/2-76-151, May, 1976.

Descriptors: Pollutants, Pollutant idenfication, Pollution abatement, Water pollution, Water pollution sources, Water quality, Water quality control, Water resources.

The rates and magnitudes of discharges of pollutants from nonpoint sources do not relate simply to source characteristics or source-related parameters. Evaluation of the severity of this problem is hampered by the lack of tools to quantify pollutant loads, and scanty and inprecise data on the interrelationships between control measures and pollutant loads are a deterrent to formulation of control or regulatory strategies. This User's Handbook is the result of a program which had as one objective the development of nonpoint pollution loading functions for significant sources and significant pollutants. The Handbook has two basic functions. First, it presents loading functions together with the methodologies for their use. Second, it presents some of the needed data, provides references to other sources of data, and suggests approaches for generation of data when available data are inadequate. A corollary function consists of assessments of the adequacies of functions and their supporting inventories of data, and an assessment as well of the extent to which pollutants and nonpoint sources are adequately covered.

76:05B-052
SIMULATION OF AGRICULTURAL RUNOFF,
Donigan, A.S., Jr., and Crawford, N.H.
Hydrocomp Incorporated, Palo Alto, California 94304
Presented at the National Water Resources and Ocean Engineering Convention of the American Society of Civil Engineers, April 5-8, 1976, San Diego, California, 26 p, 7 fig, 15 ref.

Descriptors: Model studies, Return flow, Runoff, Sediments, Sedimentation, Pesticides, Nutrients, Simulation analysis, Georgia, Water quality, Snowmelt, Watershed management.

Modifications, testing, and further development of the Pesticide Transport Runoff Model have produced the Agricultural Runoff Management (ARM) Model. The ARM Model simulates runoff, snow accumulation and melt, sediment loss, pesticide-soil interactions, and soil nutrient transportation on small agricultural watersheds. This paper briefly describes the ARM Model and discusses the results of Model testing for simulation of runoff, sediment, and pesticide loss. Due to lack of data, the nutrient model was not tested with observed data; testing and refinement of the nutrient algorithms is expected to begin in the near future.

76:05B-053
NITRATE IN EFFLUENTS FROM IRRIGATED LANDS,
Pratt, P.F., Broadbent, F.E., McLaren, A.D., et al.
University of California, Kearney Foundation of Soil Science, Riverside, California 92502
Environmental Protection Agency Report No. PB-260 514, July, 1976.

Descriptors: Effluents, Leaching, Irrigated land, Percolation, Nitrogen cycle, Water flow, Soil mechanics, Return flow, Nutrients.

The objective of this program is to develop a capability to predict nitrate leaching in drainage and percolating waters from irrigated lands. The program is subdivided into projects: (1) extensive field approaches to assess nitrate concentrations and quantities of nitrate-nitrogen leached; (2) intensive field trials using stable isotopes of nitrogen to follow its fate through the soil-crop system; and (3) nitrogen transformations in the soil and the microbiological and physical factors that control these transformations. One project deals with computer modeling of the soil-crop-water system. There is a need to know as much as possible concerning all aspects of the nitrogen cycle in the soil-plant-water system, i.e., cycling in the system, fluxes into harvested crops, drainage or percolating waters, and denitrification and ammonia volatilization into the atmosphere. To predict the leaching of nitrate from irrigated lands one must also understand and predict water fluxes. One of the dominant factors in nitrogen use efficiencies in the system is water management, thus many papers deal with the problem of predicting downward fluxes of water in a dynamic situation involving irrigation cycles and a growing crop.

76:05B-054
FATE OF SALTS FROM WATER AND MANURE IN A 4-YEAR FIELD EXPERIMENT,
Pratt, P.F., Davis, S., Adriano, D.C., Bishop, S.E., and Laag, A.E.
California University, Department of Soil Science and Agricultural Engineering, Riverside, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 264-276. 3 fig, 5 tab, 9 ref.

Descriptors: Calcium, Magnesium, Sodium, Potassium, Drainage water, Farm wastes, Irrigation water, Return flow, Leaching.

The removal of Ca, Mg, Na and K in harvested crops and in drainage waters was measured for a 4-year experiment with animal manures. For each cation the amount added in irrigation water and in manures minus removals in crops and by leaching was assumed to have accumulated in the root zone of the soil. Calcium, Mg and K accumulated in the root zone whereas there was a net loss of Na. The dominant cation in the percolating water was Na, followed by Ca and then by Mg. Very little K was removed by leaching. The dominate anion in the percolating water was Cl. The determined increase in carbonate, expressed as $CaCO3$, in the soil was correlated with the calculated Ca accumulation in the root zone. The calculated Ca precipitated as octacalcium phosphate assuming that all of the fixed P converted to this form, was about 40% of the total Ca accumulation in the root zone. Accumulation of soluble salts in the root zone accounted for only about 6% of the total cation accumulation and there was no increase in CEC. Thus, the main mechanism for cation accumulation was precipitation or fixation.

76:05B-055
DISTRIBUTION AND SEASONAL VARIABILITY OF MICRONUTRIENTS IN CERTAIN SALT AFFECTED SOILS OF NORTHERN GREECE,
Papanicolaou, E.P., Anagnostopoulos, Tr., and Nobeli, C.
N.R.C. 'Democritos', Aghia Paraskevi, Athens, Greece.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 175-186. 12 fig. 19 ref.

Descriptors: Nutrients, Salts, Zinc, Iron, Copper, Boron, Soil salinity, Manganese, Leaching.

In two salt affected areas of Northern Greece the distribution and seasonal variability of B, Cu, Mn, Zn, and Fe along with the distribution and variability of salts are presented. The levels of boron are high in the soils of both areas and probably toxic to various plant species depending upon their relative tolerance to this element. Copper and iron are probably present in normal levels while the levels of manganese and zinc are probably low for the soils of both areas. Regarding seasonal variability there is evidence of leaching for boron, copper, zinc, and iron and also for salts during the rainy period, while the data for manganese are rather inconclusive. It is concluded that considerable amounts of micronutrients will be leached out of these soils during reclamation.

76:05B-056
DETAILED RETURN FLOW SALINITY AND NUTRIENT SIMULATION MODEL,
Shaffer, M.J.
United States Bureau of Reclamation, Denver, Colorado.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 127-141. 8 fig, 18 ref.

Descriptors: Model studies, Simulation analysis, Drainage, Nitrogen, Nutrients, Return flow, Water quality, Lysimeters, Irrigation effects, Salinity.

A computer model allows the simultaneous consideration of many complex chemical and physical processes in the unsaturated and saturated zones. The model simulates one-dimensional unsaturated flow and two-dimensional saturated flow (to tile drains), as well as chemical reactions and transport processes involving the major cations and anions, and nitrogeneous species. The program also includes crop uptake of water and nutrients. A numerical integration technique is utilized to solve the appropriate differential equations, and generate transient predictions throughout the soil-aquifer system, and at the drains. Utilization of a master site technique allows application of the model to predict irrigation return flow quality and quantity from large irrigated areas involving thousands of acres. Verification has been accomplished on large acreages as well as field plots, lysimeters, and laboratory columns. The model has a well-documented user's manual and has been applied to several large irrigation projects.

76:05B-057
A CONCEPTUAL HYDROSALINITY MODEL FOR PREDICTING SALT LOAD IN IRRIGATION RETURN FLOWS,
Tanji, K.K.
California University, Department of Land, Air, Water Resources, Water Science and Engineering Section, Davis, California.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 49-70. 6 fig, 6 tab, 13 ref, append.

Descriptors: Model studies, Simulation analysis, Salinity, Return flow, Irrigation, Irrigation effects.

Presented herein is a description and applications of a steady-state conceptual hydrosalinity model. The model may serve as a first-order approximation in lieu of more detailed and refined models for evaluating mass emission of salts from irrigated agriculture.

76:05B-058
HYDROSALINITY MODELING OF IRRIGATION RETURN FLOW IN THE MESILLA VALLEY, NEW MEXICO
McLin, S.G., and Gelhar, L.W.
New Mexico Institute of Mining and Technology, Socorro, New Mexico.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 28-48. 7 fig, 2 tab, 28 ref.

Descriptors: New Mexico, Model studies, Simulation analysis, Aquifers.

The preliminary simulation results for the Mesilla Valley indicate a need to improve the input data and model structure. Several sensitivity analyses conducted with the model in its current preliminary form show the effects of consumptive water use, soil chemistry, and the groundwater chemistry. The scheme currently used in the model to transfer water between the aquifer and the stream may be physically unrealistic in that it is independent of aquifer properties and water level. Improvements which relate the stream-aquifer interaction to aquifer properties and water level will be incorporated after the model has been tested over a long time frame in its current form. Baseflow recession and well drawdown data will be used to estimate the required aquifer parameters for the proposed model improvements.

76:05B-059
IRRIGATION MANAGEMENT WHERE SALINITY SOURCES AND SINKS ARE PRESENT,
Hanks, R.J., Willardson, L.S., Jurinak, J.J., and Melamed, J.D.
Utah State University, Department of Soil Science and Biometerology, Logan, Utah
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 15-27. 6 fig, 1 tab, 14 ref.

Descriptors: Salinity, Salts, Saline soil, Irrigation water, Irrigation, Irrigation effects.

Where sources and sinks are presented irrigation must be modified considerably. Sources and sinks are found where salts have precipitated out of the soil solution (Sink) or dissolved into the soil solution from solid phase salts (Source). An empirical addition to a previous model was devised to account for these source-sinks which were found to be very important in the field at Ashley Valley, Utah. The model predicts that where sources are present, irrigation management variations has little influence on profile soil salinity for many years. Similarly it predicted that salt concentration into the drainage water will not change for many years regardless of the irrigation management used. Where a water table is present irrigation less than enough to meet evapotranspiration demands will be possible for many years with no adverse affect. These predictions agree with field measurements.

SECTION XXV

WATER QUALITY MANAGEMENT AND PROTECTION

EFFECTS OF POLLUTION (GROUP 05C)

76:05C-001
SIGNIFICANCE OF WATER QUALITY TO WATER RESOURCES,
Valantine, V.E.
Colorado River Board of California, Los Angeles, California.
Presented at the National Water Resources and Ocean Engineering Convention of the American Society of Civil Engineers, April 5-8, 1976, San Diego, California, 13 p, 1 tab, 4 ref.

Descriptors: Water quality, Dissolved solids, Saline water, Economics, Water resources, Water quality control.

Of the parameters of water quality, the dissolved solids or salinity parameter requires special attention by water resources planners as it cannot be controlled by filtration or biological reduction processes. As salinity levels in a water supply rise, users of that supply are subject to detrimental effects that impose substantial costs on the users. With the increased recognition of these detrimental effects and their costs in recent years, conflicts have arisen between the groups of users causing salinity increases and those experiencing their impacts. To resolve these conflicts, special public works projects have been and are continuing to be constructed, changes costly of both water and money have been and are continuing to be made in the operation of water resource projects. and private investment plans are restructured at increased costs.

76:05C-002
MANAGING SALINE WATER FOR IRRIGATION,
Texas Tech University, International Center for Arid and Semi-Arid Land Studies, Lubbock, Texas
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976. 618 p.

Descriptors: Irrigation, Irrigation water, Irrigation effects, Salinity, Saline soil, Saline water, Water quality, Water quality control, Energy, Saline water systems, Salt balance, Salts, Model studies, Simulation analysis, Crop production.

Irrigation water salinity is becoming an increasingly serious problem as water of less and less desirable quality is exploited for irrigation and as greater intensity of water use leads to degradation. Deteriorating quality, combined with rapidly increasing energy costs, has caused a crisis in water use in pump-irrigated areas. Similarly, river waters have become more highly regulated, water evaporating from reservoirs concentrates the salts, and new irrigation projects aggravate the salinity problem for downstream users. An international conference was held at Texas Tech University in 1976 to assess the current state of knowledge about managing saline water for irrigation and to present new information on how to cope with salinity. Plant scientists, soil scientists, and engineers representing 20 countries participated in the sessions. Their findings are presented in this volume. The tone of the papers is one of optimism that moderately saline water can be used successfully for irrigation if what is known already and what is being learned now is used effectively. Mixed with the optimism is the realization that careless management of saline irrigation water can be disastrous to the land and, more importantly, to the people living on that land.

SECTION XXVI

WATER QUALITY MANAGEMENT AND PROTECTION

WASTE TREATMENT PROCESSES (GROUP 05D)

76:05D-001
EVALUATION OF A SULFUR-THIOBACILLUS DENITRIFICANS NITRATE REMOVAL SYSTEM,
Sikora, L.J., and Keeney, D.R.
Agricultural Research Service, Beltsville, Maryland.
Journal of Environmental Quality, Vol. 5, No. 3, p 298-303, July-September 1976.
6 fig, 3 tab, 32 ref.

Descriptors: *Denitrification, *Septic tanks, *Sewage treatment, *Domestic wastes, *Nitrates, *Biological treatment, Bacteria, Sulfates, Groundwater, Sulfur, Carbon, Inorganic compounds, Organic compounds, *Waste water treatment, Kinetics, Chemical reactions.

A sulfur-Thiobacillus denitrificans nitrate removal system was evaluated as a means of denitrifying nitrified septic tank effluent. Duplicate 10 by 64 cm columns were filled with a 1/1 mixture (by weight) of elemental sulfur and dolomite chips and were pretreated by recycling an enrichment culture of Thiobacillus denitrificans ATCC 23642 through the columns for 3 days. Continuous passage of the nitrified septic tank effluent containing 40 micrograms of nitrate/milliliter through the columns resulted in nearly complete nitrate removal in 3.3 hours at steady state conditions. The denitrification kinetics appeared to be first order in the range of nitrate concentrations used. Sulfate was the major sulfur end product and was present at relatively high concentrations (90 micrograms/milliliter). Passage of column effluent through 10 by 60 cm Plainfield sand columns did not significantly decrease sulfate levels. A significant decrease in inorganic carbon content occurred with depth in the columns, but changes in organic carbon were insignificant. Although the use of this nitrate removal system appears promising, sulfate contamination of the groundwater may limit its applicability.

76:05D-002
SOIL TEMPERATURES AND HEAT LOSS FOR A HOT PIPE NETWORK BURIED IN IRRIGATED SOIL,
Alpert, J.E., VanDemark, S.C., Fritton, D.D., and DeWalle, D.R.
Energy Resources Company, Envrionmental Science, Cambridge, Massachusetts.
Journal of Environmental Quality, Vol. 5, No. 4, p 400-405, October-December 1976. 5 fig, 3 tab, 15 ref.

Descriptors: *Heat, *Temperature, *Waste water disposal, Soil temperature, Irrigation, Irrigation effects, Thermal conductivity, Heat flow, Model studies.

A 0.09-ha field prototype of a simultaneous waste heat and waste water disposal system was constructed and instrumented. Data are reported for soil, pipe, soil surface, and air temperatures; heat loss (0.068-0.117 cal cm(-2) min(-1)); and soil thermal conductivity (3.61-5.63 mcal (cm sec degrees C)(-1)). The data are used to evaluate the heat flow theory which is currently being used to predict the land area required for waste heat disposal with a buried hot water pipe network. Predicted heat loss was consistently lower than experimental heat losses. The results of the experiment indicate that substantial improvements need be made in the existing theory to account for the transient heat flow and heat storage. Research is currently being conducted to develop better predictive models.

76:05D-003
OPTIMAL GROUND WATER QUALITY MANAGEMENT: WELL INJECTION OF WASTE WATERS,
Willis, R.
Cornell University, School of Civil and Environmental Engineering, Ithaca, New York.
Water Resources Research, Vol. 12, No. 1, p 47-53, February 1976. 2 fig, 3 tab, 24 ref.

Descriptors: *Mathematical models, *Aquifers, *Waste water treatment, *Water quality, Water treatment, Cost-benefit analysis, Groundwater, *Injection wells.

A mathematical model for optimal conjunctive utilization of the ground water quality and quantity resources of unconfined aquifers was constructed. The saturated zone of the ground water system was considered a component of a regional waste treatment system. The model was designed so as to minimize the cost of surface waste treatment while maintaining acceptable water quality levels throughout the aquifer. Results indicate the feasibility of using secondary waste water treatment (trickling filter) in conjunction with the assimilation capacity of the unconfined aquifer for waste water degradation and disposal.

76:05D-004
SOIL TEMPERATURE INCREASES INDUCED BY SUBSURFACE LINE HEAT SOURCES,
Rykbost, K.A., Boersma, L., and Jarman, G.D.
Long Island Vegetable Research Farm, Riverhead, New York 11901
Agronomy Journal, Vol. 68, No. 1, p 94-99, January-February 1976. 2 fig, 5 tab, 14 ref.

Descriptors: Temperature, Soil temperature, Heat, Heat transfer, Economics, Energy, Energy conversion.

Generating electricity using the steam cycle produces large quantities of waste heat. Conversion efficiencies range from 32 to 38% which means that for three units of energy input about one unit of electrical energy is produced and two units of waste heat must be disposed of. Circulating the condenser cooling water through a network of underground pipes would result in warming the soil. The present study was initiated to evaluate the effect of increased soil temperatures on crop growth, the energy balance of the proposed system, and the economic feasibility of the system. This report presents results of the energy balance studies.

76:05D-005
UNIFORM SLURRY SPREADING WITH A CENTER PIVOT IRRIGATION SYSTEM,
Chapman, J.A. and Myers, R.G.
Valmont Industries, Incorporated, Valley, Nebraska
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 11 p, 4 fig, 3 ref.

Descriptors: Farm waste, Sprinkler irrigation, Irrigation, Irrigation practices, Economics.

A design for the automated distribution of liquid manure through center-pivot irrigation systems has been developed. The design is functionable and achieved its basic goals. Under many conditions it appears to be highly cost effective when compared to current liquid manure handling systems.

SECTION XXVII

WATER QUALITY MANAGEMENT AND PROTECTION

ULTIMATE DISPOSAL OF WASTES (GROUP 05E)

76:05E-001
PROCEEDINGS OF THE CONFERENCE ON SALT AND SALINITY MANAGEMENT,
California University, Davis, California 95616
Proceedings of the Conference held at Santa Barbara, California, September 23-24, 1976, Report #38, December 1976. 166 p.

Descriptors: *Salts, *Salinity, *Water management, *Water quality control, *Legislation, *Political aspects, *Institutions, Irrigation, Waste water disposal, California, Operations, Technology, Soil tolerance, Water utilization.
(see 76:05G-020)

SECTION XXVIII

WATER QUALITY MANAGEMENT AND PROTECTION

WATER TREATMENT AND DISTRIBUTION (GROUP 05F)

76:05F-001
VYREDOX-IN SITU PURIFICATION OF GROUNDWATER,
Hallberg, R.O., and Martinell, R.
Stockholm University, Department of Geology, (Sweden).
Ground Water, Vol. 14, No. 2, p 88-93, March-April 1976. 6 fig, 1 tab, 22 ref.

Descriptors: *Iron, *Manganese, Permeability, *Water treatment, Iron bacteria, Clogging, Aeration.

The abundance and relative purity of groundwater guarantees its increase in usage. In some localities, the content of iron and manganese in groundwater is so high that these metals must be removed before the water can be used for drinking or industrial purposes. Iron occurs in two states of oxidation in nature, the divalent (ferrous) and trivalent (ferric) forms. The Vyredox method developed in Finland and used now in Sweden oxidizes the ferrous ion, which is soluble in water, to the ferric ion, which in insoluble, before the water enters the well. The Vyredox method achieves a high degree of oxidation in the strata around the well. The method makes use of iron oxidizing bacteria and aeration wells. A number of aeration wells are placed in a ring around the supply well. Water is forced down the aeration wells but first it is degassed and then enriched with oxygen. The oxygen rich water provides a suitable habitat for the iron oxidizing bacteria which assist in the oxidation of ferrous iron. The process must be repeated at specific time intervals to avoid further increases of iron content. The process of precipitating iron in the aquifer has only a slight effect on aquifer permeability. Cloggage of the aquifer surrounding the well should not occur for a period many times longer than the life span of a typical well. Formulas provide estimates of the time in which aquifer cloggage can occur and the radius at which aeration wells should be placed.

SECTION XXIX

WATER QUALITY MANAGEMENT AND PROTECTION

WATER QUALITY CONTROL (GROUP 05G)

76:05G-001
SULFURIC ACID FOR THE TREATMENT OF AMMONIATED IRRIGATION WATER: II. REDUCING CALCIUM PRECIPITATION AND SODIUM HAZARD,
Miyamoto, S., and Ryan, J.
New Mexico State University, Department of Agronomy, Las Cruces, New Mexico.
Soil Science Society of America Journal, Vol. 40, p 305-309, 1976. 1 fig, 6 tab, 13 ref.

Descriptors: *Irrigation operation and maintenance, *Hydrogen sulfide, *Mine wastes, *Irrigation efficiency, Water utilization, Water quality, Southwest U.S., Infiltration, Ammonia, Lime, Chemical wastes, Industrial wastes, Pollution abatement, Fertilizers.

Effects of the application of ammonia and sulfuric acid to ammoniated water on Calcium precipitation and Na-Hazard of irrigation water are evaluated theoretically, using known relations of ion equilibria, and tested with laboratory and greenhouse experiments. Results show severe precipitation of Ca2+ when ammonia is applied to alkaline irrigation water. Ammonia application also increases exchangeable Na and NH4, and can reduce water infiltration rates, especially when irrigation waters contain high Na+ relative to Mg2+ and Ca2+. Sulfuric acid applied to ammoniated water neutralizes OH- produced by ammonia application, reducing Ca precipitation and exchangeable Na. This prevents a decline in infiltration rates. Sulfuric acid, now available as a pollution abatement by-product in the Southwest, can be used for correcting excessive lime incrustation or poor water penetration induced by the use of hydrous or aqua ammonia without corroding irrigation systems.

76:05G-002
GUIDELINES FOR SEDIMENT CONTROL IN IRRIGATION RETURN FLOW,
Carter, D.L.
Agricultural Research Service, Snake River Conservation Research Center, Kimberly, Idaho.
Journal of Environmental Quality, Vol. 5, No. 2, p 119-124, April-June 1976. 1 tab, 17 ref.

Descriptors: *Return flow, *Erosion control, *Irrigation practices, *Irrigation water, *Sediment control, Water quality, Agriculture, Runoff, Flow, Furrow irrigation, Erosion, Cultivation, Filtration.

Sediments in irrigation return flows arise mostly from erosion in furrows during irrigation, and sediment concentrations vary widely from near zero to several thousand ppm. Reducing both erosion and runoff would decrease the sediment in return flows. Technology is available for reducing both erosion during irrigation and soil loss from the land, and for removing sediments from return flows. This technology was discussed, and the following guidelines were suggested: (1) Eliminate or reduce irrigation return flows when conditions permit using irrigation methods with little or no runoff. (2) Control the irrigation furrow slope so that the run is across the steepest slope or on the contour. Decrease the slope near the end of the furrow to reduce the flow velocity and increase sedimentation. (3) Control the furrow stream size and make proper stream adjustments. Adequate water measuring equipment and controls are essential for proper stream size control. (4) Shorten the run length. (5) Control the irrigation duration to reduce the number of irrigations per season. Alternate furrow irrigation reduces the contact between soil and flowing and subsequent erosion. (6) Cultivate only when necessary, avoiding excessive soil loosening which increases erosion and soil loss. (7) Control tailwater by assuring that it flows slowly enough that sediments settle before the water leaves the field. Filtering through grass strips removes sediments. (8) Utilize sediment retention basins to remove sediment from return flows.

76:05G-003
HYDROLOGY OF SALINE SEEPS IN THE NORTHERN GREAT PLAINS,
Doering, E.J., and Sandoval, F.M.
Agricultural Research Service, Northern Great Plains Research Center, Mandan, North Dakota.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 5, p 856-861, 865, September-October 1976. 7 fig, 4 tab, 16 ref.

Descriptors: *Seepage, *Groundwater movement, *Water quality, *Seepage control, *North Dakota, On-site investigations, On-site tests, Measurement, Instrumentation, Saline water, Salinity, Nitrates, Chlorides, Hydrographs, Hydrology, Groundwater, Subsurface drainage, Tile drainage, Hydrologic data.

Hydrologic data collected between 1970 and 1975 show: (1) that seeps are sustained by local recharge, i.e., by soil water that percolates past the root zone of the adjacent upslope landscape, (2) that seep development is closely related to recent climatic and cultural events, and (3) that hydraulic control can be quickly accomplished with interceptor drains. Effluents from two drains were saline, with nitrate concentrations consistently high enough to be hazardous to health of humans and livestock.

76:05G-004
THE ROLE OF SYSTEMS ANALYSIS IN THE USE OF AGRICULTURAL WASTES,
Schlute, D.D., and Kroeker, E.J.
Manitoba University, Department of Agricultural Engineering, Winnipeg, Manitoba, Canada.
Journal of Environmental Quality, Vol. 5, No. 3, p 221-227, July-September 1976. 4 fig, 21 ref.

Descriptors: *Systems analysis, Wastes, Model studies, Simulation analysis, Linear programming, Dynamic programming.

Agricultural waste management is a multidisciplinary field which has grown in an attempt to solve problems of agricultural by-product utilization and disposal. Development of meaningful solutions to agricultural waste management problems will be much simpler if practitioners and researchers educate one another and together work to solve the different problems of the producer. Many disciplines have already become involved in the problem-solving process; yet, there is a need for a generalist in agricultural waste management who can bridge disciplinary gaps and promote effective cooperation between specialists in various fields of study. Systems analysis can serve a useful purpose in agricultural waste management by providing a focal point for cooperation between disciplines working on various aspects of the problem. Systems analysis has been used to: (i) provide a common structure for comparison of agricultural waste management strategies; (ii) identify processes or links within waste-utilization systems which are costly or sensitive to operating conditions; (iii) predict effects of external constraints such as government policy, fertilizer taxes, and prices on the effectiveness of waste-utilization strategies; (iv) yield information to predict where research funds would be spent most effectively; and (v) assist in technology transfer from researchers to practitioners through the aid of computer-based education models.

76:05G-005
DIFFUSE AGRICULTURAL POLLUTION: THE ECONOMIC ANALYSIS OF ALTERNATIVE CONTROLS,
Schneider, R.R., and Day, R.H.
Wisconsin University, Department of Agricultural Economics, Madison, Wisconsin.
Wisconsin Water Resources Center, Madison, Technical Report WIS WRC, 1976.
98 p 76-02, 16 fig, 30 tab, 8 maps, 72 ref. 2 append. OWRT A-063-WIS(2).
14-31-0001-5050.

Descriptors: *Agricultural runoff, *Nitrates, *Sediment yield, *Sediments, *Nutrients, Agriculture, *Farm management, Crops, *Fertilizers, *Water pollution sources, *Farm wastes, Legislation, *Wisconsin, Water policy, Water pollution control, Alternative planning.

This study examines policies designed to curtail 3 types of diffuse agricultural pollution: (1) Runoff from winter-spread manures; (2) Sediment in rill and sheet erosion; (3) Nitrate polution of groundwater resulting from field-applied manure and chemical nitrogen. The following policies are tested on four farm sizes at 7 locations: (1) enfource Wisconsin's Model Sediment Control Ordinance; (2) prohibit all manure spreading in winter; (3) prohibit winter manure spreading on sloped land; (4) prohibit winter manure spreading close to streams, lakes, or open ditches; (5) restrict the excess of applied nitrogen over estimated plant uptake of nitrogen; (6) combine 1, 3, 4, and 5 above; (7) combine 1, 2, and 5 above,; (8) restirct average total sediment yield. The effects of these policies on efficiency of resources allocation, and their differential impact in the glaciated and unglaciated regions of the state are explored. The framework for efficiency analysis is that of a partial competitive equilibrium. The estimation of appropriate data for the analysis is an important and integral part of the study. The marginal cost of pollution reduction is calculated for each policy and the marginal cost curve is generated for a sediment policy on selected farms. These data are presented along with the physical quantities of pollutant reduction.

76:05G-006
THE INFLUENCE OF TRICKLE IRRIGATION ON THE QUALITY OF IRRIGATION RETURN FLOW,
Brown, K.W., Gerard, C.J., DeMichele, D.W., Sharpe, P.J.H., and Hipp, B.W.
Texas A and M University, Department of Soil and Crop Sciences, College Station, Texas.
Texas Water Resources Institute, College Station, Completion Report TR-70, March, 1976. 77 p, 3 fig, 19 tab, 10 ref. OWRT B-156-Tex(1), 14-31-0001-4128.

Descriptors: Water quality, *Leachate, Leaching, Sorghum, *Rio Grande River, *Return flow, *Texas, Nitrates, *Lysimeters, *Salt balances, *Computer models, Simulation analysis, Soil treatment, Crop production, Irrigation water.

The influence of trickle irrigation on the quality of irrigation return flow was investigated in a field study and by means of computer simulation models. Six undisturbed buried monolith lysimeters were utilized to quantify the leachate from treatment including two different qualities of irrigation water applied through a trickle irrigation system. Both moisture and salt balances were followed indise and outside the lysimeters during a growing season the remainder of the calendar year. A sorghum crop was grown on the lysimeters and in the adjacent area. Irrigation was scheduled based on pan evaporation losses. The irrigation water of high salt content was obtained from a deep well while the irrigation water of low salt content was drawn from the district irrigation canal. The water balance monitored by the neutron probe showed that differences between inside and outside lysimeters were small. The soil contained significant concentration resulting from irrigation treatment are difficult to see after one year of monitoring. Differences between paired lysimeters are large indicating large variability in soil characteristics across the field. Differences in water use inside and outside the lysimeters indicated that during the 1974 growing season, which was dryer than normal, the sorghum crop may have extracted approximately 8% of the water required from the water table. Yield and growth data indicated that the plant root environments inside and outside lysimeters were relatively comparable. Nitrogen, saline water and irrigation treatments did not significantly influence growth and yields of sorghum in 1974.

76:05G-007
LOSSES OF NITROGEN IN SURFACE RUNOFF IN THE BLACKLAND PRAIRIE OF TEXAS,
Kissel, D.E., Richardson, C.W., and Burnett, E.
Texas Agricultural Experiment Station, College Station, Texas.
Journal of Environmental Quality, Vol. 5, No. 3, p 288-293, July-September 1976. 4 tab, 1 fig, 16 ref.
(see 76:05B-018)

76:05G-008
AN OPTIMIZATION MODEL FOR REGIONAL WATER QUALITY MANAGEMENT,
McNamara, J.R.
Lehigh University, Department of Economics, Bethlehem, Pennsylvania.
Water Resources Research, Vol. 12, No. 2, p 125-134, April 1976. 3 fig, 2 tab, 26 ref.

Descriptors: *Water quality, *Management, *Pollution abatement, *Optimization, *Hudson River, Waste treatment, Marginal costs, Flow, Regulation, Biochemical oxygen demand, Constraints, Decision making, Mathematical models, Equations, Systems analysis, *New York.

The use of combinations of pollution abatement techniques will become imperative in coming years as waste loads increase and the application of secondary level treatment at each point of discharge becomes inadequate to maintain the desired levels of water quality. At high levels of waste treatment, costs rise nonlinearly with the fraction of waste removed. The marginal cost of each of a series of pollution abatement techniques at a given location is likely to be less than the marginal cost of a single technique operated very intensively. Herein, a nonlinear programming model for water quality management is developed, capable of assessing the contributions of a variety of pollution abatement techniques and compatible with an efficient solution procedure. Formulated as a geometric programming problem, the model is intended to be a preliminary selection device permitting the planner to compare alternative configurations and to sketch a roughly optimal solution. It is shown that this formulation permits the simultaneous consideration of waste treatment processes, bypass piping, flow regulation, and artificial aeration in determining a least-cost solution to a given water quality management problem. The model is applied to the upper Hudson River of New York.

76:05G-009
FIELD DRAINAGE WITH MANIFOLD WELL POINTS,
Rektorik, R.J.
Agricultural Research Service, Weslaco, Texas.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 81-84, January-February 1976. 2 fig, 4 tab, 6 ref.

Descriptors: *Drainage systems, *Drainage wells, *Rio Grande River, *Texas, Water quality control, Aquifers, Plastic pipes, Well screens, Water table, Dewatering, Drawdown, Drainage, On-site investigations, Leaching, Cost analysis, Depth, Transmissivity, Storage coefficient, Pumping, Electric power costs, Centrifugal pumps, Reclamation, Root zone, Hydraulic gradient, Cathodic protection, Corrosion, Electrolysis.

A field study of a maniforl well point system was conducted in a highwater table, shallow aquifer in the lower Rio Grande Valley of Texas. The objectives of the study were to determine how effectively well point drainage systems work, how long they would last, their design, and their installation and operational cost. PVC pipe was used for the wells and manifold piping, and plastic screens were used for the well points. These materials offer much resistance to both corrosion and electrolytic problems and, as such, show promise for a long service life. The cost of well point systems at about $250/ha is materially lower than the (370-$500/ha for pipe drain systems. The design of well point systems depends on variations in aquifer parameters. Straight line configurations are most economical to construct but do not produce the most uniform drawdown. Water removal of about 0.26 l/s/ha provided adequate control of the water table in the study ares and permits leaching of salts by irrigation or rainfall.

76:05G-010
EQUITY CONSIDERATIONS IN CONTROLLING NONPOINT POLLUTION FROM AGRICULTURAL SOURCES,
Miller, W.I., and Gill, J.H.
Purdue University, Department of Agricultural Economics, Lafayette, Indiana.
Water Resources Bulletin, Vol. 12, No. 2, p 253-261, April 1976. 3 tab, 12 ref.

Descriptors: *Water pollution control, *Agriculture, *Linear programming, *Farms, Size, *Economic impact, *Indiana, Constraints, Research, Mathematical models, Systems analysis, Water pollution sources.

The objectives of the research reported in this paper are: (1) to compare the relative economic impact on large and small farms of applying a statewide soil loss standard to achieve specified levels of pollution control as measured in tons of soil loss per acre per year; (2) to compare the relative impact between two different topographic areas in Indiana with respect to the statewide standard; and (3) to compare the relative economic impact between large and small farms and between different topographic areas resulting from application of taxes-subsidies on soil loss. Accomplishing these objectives will illuminate some of the equity consequences of application of two quite different approaches to controlling nonpoint pollution from agricultural sources. A linear programming model has been used to analyze the objectives. The model includes an objective function to maximize model and includes objective function to maximize net revenue to the farm firm by selecting among a wide array of management parctices applied on several different soil groups. It is concluded that the imposition of standard state soil loss rules has an unequal impact on the income of different size firms located in different topographic regions.

76:05G-011
POLLUTER DISCRIMINANT ANALYSIS,
Tock, D.G., and Wright, G.P.
Krannert Graduate School of Industrial Administration, Lafayette, Indiana.
Water Resources Research, Vol. 12, No. 4, p 613-616, August 1976. 1 fig, 3 ref.

Descriptors: *Water pollution control, *Data collections, Coasts, Great Lakes, Statistical methods, Mathematical models, Systems analysis.

A unique water pollution data base for the U.S. coastal waterways and Great Lakes that has been evolving since 1965 is discussed. The pollution statistics in this data base are used to develop a model, employing multiple discriminant techniques, to determine which pollution incident report variables will discriminate the polluter who reports his spill from the polluter who does not report his spill. The results of the analysis indicate that as few as nine out of a possible sixty variables provide reasonable discriminatory power.

76:05G-012
ON THE INCOME DISTRIBUTIONAL EFFECTS OF ENVIRONMENTAL MANAGEMENT POLICIES,
Campbell, H.F.
British Columbia University, Department of Economics, Vancouver, British Columbia.
Water Resources Research, Vol. 12, No. 5, p 1077-1080, October 1976. 3 tab, 6 ref, 1 append.

Descriptors: *Water resources, *Income distribution, *Effects, *Environmental control, *Effluents, *Standards, *Treatment, Technology, Behavior, Simulation analysis, Prices, Mathematical models, Systems analysis, Optimum development plans.

This paper analyzes the effect of three environmental policy instruments--effluent charges, effluent standards, and effluent treatment subsidies--in the context of a two-person two-firm general equilibrium model in which the distribution of income varies with the choice of policy instrument. It is demonstrated that, under reasonable assumptions about the income distribution process and the nature of consumer preferences, each policy instrument corresponds to a different optimal quantity of effluent and a different set of optimal prices. The implication of this result is that consideration of income distributional effects should play an integral part in the formulation of optimal environmental management policies.

76:05G-013
CATHODIC PROTECTION WELLS AND GROUNDWATER POLLUTION,
Ritchie, E.A.
California State Department of Water Resources, Sacramento, California.
Ground Water, Vol. 14, No. 3, p 146-149, May-June 1976. 3 fig, 5 ref.

Descriptors: *Cathodic protection, *Water pollution, *Hydraulic conductivity, Groundwater, Infiltration, Wells, California, *Corrosion.

The cathodic protection well can endanger groundwater quality by providing a path for pollutants to reach usable water supplies. Cathodic protection wells alleviate electrolytic corrosion of pipelines, tanks and other installations situated in a corrosive environment. This is done by redirecting the current to a substitute anode which then deteriorates, instead of the structure being protected. Cathodic protection wells normally are from 100 to 500 feet in depth and 8 to 10 inches in diameter. To prevent cathodic protection wells from acting as conveyences for pollutants, they must be properly designed and constructed, and when their useful lives are over, properly destroyed. California has developed, and is implementing, standards covering these areas as part of its program for groundwater basin protection.

76:05G-014
ABATEMENT OF NITRATE POLLUTION IN A PUBLIC-SAFETY WELL BY ANALYSIS OF HYDROLOGIC CHARACTERISTICS
Eccles, L.A., Klein, J.M., and Hardt, W.F.
Geological Survey, Laguna Niguel, California.
Ground Water, Vol. 14, No. 6, p 449-454, November-December 1976. 6 fig, 3 ref.

Descriptors: *Water pollution sources, *Path of pollutants, *Nitrates, *Groundwater, *California, Fertilizers, Citrus fruits, Water analysis, Sampling, Pumping Water yield, Water pollution control, Methodology.

High concentrations of dissolved nitrate in the groundwater in the Redlands, California, vicinity threaten public water supplies. Dissolved nitrate-nitrogen concentrations in water from wells, which frequently exceed 10 mg/liter, are attributed to the previous applications of large quantities of commercial nitrogen fertilizer on citrus crops. In a city of Redlands public water supply well field, wells 1 and 2 normally produce water with dissolved nitrate-nitrogen concentrations of about 18 and 30 mg/liter, respectively. Well 1 is a large capacity well capable of yielding 3,700 gal/min and is the major source of water in the well field. Chemical analyses of water collected from well 1 during the first 48-hour test showed an increase in dissolved nitrate-nitrogen from 4.1 mg/liter to a maximum of almost 20 mg/liter. Dissolved nitrate-nitrogen concentrations during the 48-hour test of well 2 stayed constant at 30 mg/liter. Interpretation of the studies indicate that the upper zone of saturation is higher in concentration of dissolved nitrate. To reduce the concentration of dissolved nitrate in water from well 1, an inflatable packer was placed in the casing at 480 feet to coincide with the bottom of the clayey interval. The packer sealed off the upper part of the well and reduced dissolved nitrate-nitrogen concentrations from 20 to 4 mg/liter while only reducing well yield from 3,700 to 2,600 gal/min.

76:05G-015
NONPOINT SOURCES OF POLLUTION: A FEDERAL PERSPECTIVE,
Pisano, M.A.
Environmental Protection Agency, Division of Water Planning, Washington, D.C.
Journal of the Environmental Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. EE3, Proceedings paper 12211, p 555-565, June 1976. 3 tab.

Descriptors: *Water pollution control, *Water quality, *Runoff, *Sedimentation, *Land use, *Silts, *Storm drains, Hydrology, Irrigation, Sediments, Mining, Natural resources, Conservation, Water resources, Legislation, Federal government, Planning.

The magnitude of the nonpoint source problem nationwide calls for the establishment of State, local, and Federal measures to control existing sources and to prevent future stream degradation from additional nonpoint sources. Under the Environmental Protection Agency's (EPA) regulations, State and local water quality management agencies have the major responsibility for the planning and programs will be on preventative techniques which are referred to as "Best Management Practices" in EPA regulations and guidelines. The EPA will provide guidance and technical assistance to the states and local designated agencies. Federal agencies will be encouraged to incorporate 208 objectives into their planning processes and to provide technical assistance to other agencies. Coordinated planning and implementation of nonpoint source programs at all governmental levels should result in significant water quality improvements.

76:05G-016
NONPOINT POLLUTION: AN EPA VIEW OF AREAWIDE WATER QUALITY MANAGEMENT,
Pisano, M.
Environmental Protection Agency, Water Planning Division, Washington, D.C.
Journal of Soil and Water Conservation, Vol. 31, No. 3, p 94-100, May/June 1976.

Descriptors: *Federal Water Pollution Control Act, *Sedimentation, *Regulation, *Water quality, *Water pollution sources, Legal aspects, Legislation, Management, Monitoring, Penalties (Legal), Permits, Standards, Water policy, Water quality standards, Water treatment, Water resources, Water pollution.

Point source pollution by industrial effluents and untreated municipal sewage has been the focal point of Americal pollution control efforts. If clear water goals are to be met by the 1983 target data, however, nonpoint sources must also be given attention. These sources include agricultural and silvicultural runoff, acid mine drainage, urban runoff, and sedimentation from construction sites. Nonpoint sources account for 92 percent of all suspended solids in water. The treatment of these solids is specified in the Federal Water Pollution Control Amendments of 1972. Section 208 calls for "best management techniques" to prevent runoff, as well as other planning procedures. An analysis of the Amendment's potential for fighting nonpoint source pollution is included.

76:05G-017
NONPOINT POLLUTION AND WATER QUALITY MONITORING,
Cooley, J.
Georgia University, Athens, Institute of Community and Area Development, and
Georgia University, Institute of Ecology, Athens, Georgia.
Journal of Soil and Water Conservation, Vol. 31, No. 2, p 42-43, March-April 1976.

Descriptors: *Water quality control, *Data collections, *Water pollution, *Water pollution sources, *Monitoring, Water pollution, Water pollution effects, Control, Control systems, Data transmission, Maintenance, Measurement, Operations, Regulation, Water quality, Erosion, State governments.

Monitoring of water quality will be necessary in the effort to control nonpoint sources of pollution. In addition, baselines of water quality must be established and a continuing assessment of control programs must be provided. Any monitoring system must characterize and define trends in the physical, chemical, and biological condition of water. This monitoring, which should be conducted by the state, will determine if management practices are obtaining the desired results. Because of the cost involved in monitoring all major nonpoint sources both upstream and downstream, the author suggests that sites should be established at carefully selected indicator operations of nonpoint sources within different regions of the state. The author acknowledges, however, that current problems make such site selections untenable for the present. Regardless of site location, periodic samples should be taken when triggered by certain climatic events. The parameters of this monitoring should be controlled by a specially developed systems model of the receiving body of water. The mere outlay of large amounts of money does not guarantee quality; rather, careful preparations should be made before any monitoring system is implemented.

76:05G-018
THE IMPACT OF ENERGY DEVELOPMENT ON WATER RESOURCES IN THE UPPER COLORADO RIVER BASIN,
Flug, M, Walker, W.R., Skogerboe, G.V., and Smith, S.W.
Colorado State University, Department of Agricultural and Chemical Engineering,
Fort Collins, Colorado 80523
Final report to office of Water Research and Technology, 158 p, 31 fig, 30 tab, 42 ref.

Descriptors: Coal, Hydroelectric power, Mathematical models, Salinity, Optimization, Mining, Nuclear energy.

A mathematical model which simulates the salt and water exchange phase of potential fuel conversions has been developed based on a subbasin analysis identifying available mineral and water resources. Potential energy developments are evaluated with respect to the resulting impacts upon both the quantity and salinity of the waters in the Colorado River. Model solutions are generated by use of a multilevel minimum cost linear programming algorithm, minimum cost refering to the cost of developing predetermined levels of energy output. Level one in the model analysis represents an aggregation of subbasins along state boundaries and thereby optimizes energy developments over the five states of the Upper Colorado River Basin. In each of the five second level problems, energy developments over a subbasin division within the respective states are optimized. A generalized solution format is used so that changes can be made to the model which enable its application to other watersheds.

76:05G-019
WATER QUALITY AND AQUITARD PERMEABILITY,
Hardcastle, J.H. and Mitchell, J.K.
Idaho University, Department of Civil Engineering, Moscow, Idaho
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR2, p 205-220, June 1976. 8 fig, 1 tab, 15 ref.

Descriptors: Water quality, Groundwater, Aquifers, Clays, Salt water intrusion.

Recent studies show that deposits containing small to moderate amounts of clay minerals play a principal role in the hydraulic behavior of multiple-aquifer groundwater systems. These layers of lesser premeability, which separate and confine the more permeable aquifers are referred to as aquitards. As a consequence of seawater intrusion or ground-water recharge, aquitards can be exposed to large and relatively rapid changes in the types and concentrations of dissolved salts contained in their pore water. This paper presents the results of an experimental study conducted to examine relationships between adsorbed cation types, the permeability of aquitard sediments, and changes in dissolved salt concentrations. The soils and solutions used were designed to simulate conditions that could occur in aquitards of coastal ground-water basins. The behavior of the artificial aquitards sediments is compared to published results for other clay soil types. The results are evaluated with respect to their significance in seawater intrusion and ground-water recharge.

76:05G-020
PROCEEDINGS OF THE CONFERENCE ON SALT AND SALINITY MANAGEMENT,
California University, Davis, California 95616
Proceedings of the Conference held at Santa Barbara, California, September 23-24, 1976, Report #38, December 1976. 166 p.

Descriptors: *Salts, *Salinity, *Water management, *Water quality control, *Legislation, *Political aspects, *Institutions, Irrigation, Waste water disposal, California, Operations, Technology, Soil tolerance, Water utilization.

The conference concentrated on legislative and political aspects of salt and salinity management together with better understanding of new technology that affects operations and management. Not included any consideration of desalting technology--which could occupy an entire conference by itself--nor some of the theoretical and methodological modeling that is continually pushing back the frontier of knowledge. Concentrated on topics and an orientation that will be most immediately useful to those of you concerned with management and operation of water systems who must cope with the problems of salt and salinity management.

76:05G-021
NITRIGEN AND IRRIGATION MANAGEMENT TO REDUCE RETURN-FLOW POLLUTION IN THE COLUMBIA BASIN,
NcNeal, B.L. and Carlile, B.L.
Washington State University, Department of Agronomy and Soils, Pullman, Washington 99163
Environmental Protection Agency Report No. 600/2-76-158, September, 1976.

Descriptors: Nitrogen, Leaching, Crop production, Potatoes, Washington, Colorado river, Nutrients, Fertilizers, Fertilization, Nitrification, Sprinkler irrigation, Irrigation, Irrigation systems, Furrow irrigation, Sampling.

Cooperative field studies have evaluated dissolved-N levels and leaching, and corresponding crop yields, for potato production practices in the Columbia Basin area of Washington. High dissolved-N levels (with resultant high potential for return-flow pollution) were found throughout the growing season in well-managed potato fields, with levels decreased by decreasing fertilization rate, use of slow-release N fertilizers or nitrification inhibitors, or sprinkler application of N fertilizers. Careful water management with solid-set sprinklers proved capable of maintaining dissolved-N within the root zone of subsequent crops by season's end, even on very sandy sites. Alternate-furrow irrigation proved effective in 'trapping' banded fertilizer N within the plant root zone on heavier-textured furrow-irrigated soils. Periodic 'mining' of residual N by other crops in the rotation would still be necessary to prevent eventual return-flow contamination, however.

76:05G-022
ACCELERATED SALT TRANSPORT METHOD FOR MANAGING GROUND WATER QUALITY,
Helweg, O.J. and Labadie, J.W.
California University, Department of Civil Engineering, Davis, California 95616.
Water Resources Bulletin, Vol. 12, No. 4, p 681-693, August 1976. 6 fig, 1 tab, 9 ref.

Descriptors: Salt, Salinity, Groundwater, Water quality, Return flow, Saline soils.

The problem of ground water degradation from irrigation and present approaches to controlling ground water quality are briefly reviewed. As an alternative to these approaches, a management scheme called the Accelerated Salt Transport (ASTRAN) method is proposed as being a feasible solution to the problem of salt build-up in irrigated areas. A management algorithm for implementing the ASTRAN method is described. Results from modeling studies indicate that the ASTRAN method is cost-effective and encourages conjunctive use of ground water and surface water.

76:05G-023
A NOTE ON THE USE OF ECONOMIC INCENTIVES IN WATER POLLUTION ABATEMENT,
Bundgaard-Nielsen, M.
Technical University of Denmark, Department of Chemical Engineering Economics, B. 227, 2800 Lyngby, Denmark
Water Resources Bulletin, Vol. 12, No. 4, p 755-758, August 1976. 1 fig, 1 tab, 6 ref.

Descriptors: Management, Economics, Taxes, Water pollution, Water pollution control.

The firms decision to invest in wastewater treatment facilities is influenced by the economic incentives provided. It is shown that the timing of investments in pollution control may be described by an extended version of the first year benefit criterion. The criterion developed may help to provide a better insight into the complex interaction of the various economic incentives used in pollution abatement.

76:05G-024
INTEGRATING DESALINATION AND AGRICULTURAL SALINITY CONTROL TECHNOLOGIES,
Walker, W.R.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 71-94. 7 fig, 3 tab, 11 ref.

Descriptors: Salinity, Water quality, Return flow, Seepage, Desalination, Optimization, Colorado, Economics.

In viewing salinity management on a regional basis, the strategies for improving the quality of irrigation return flows are important considerations. Alternatives for reducing salinity in these flows include traditional treatments like conveyance channel linings to eliminate seepage as well as new technologies such as desalination. A general approach is presented for determining the optimal use of both measures and is demonstrated with a case study applied to Colorado's Grand Valley. Relationships descriptive of irrigation conveyance linings and desalination using a reverse osmosis process are combined with anticipated salinity reductions in return flows entering the Colorado River. The resulting cost-effectiveness functions are then optimized to determine the best use of either technology for salinity control. Results indicate that linings, and probably other agricultural treatments as well, exhibit increasing marginal costs with scale. Desalting costs show a reverse trend. These findings imply that most salinity control in the early stages of implementation will involve agricultural measures almost exclusively. At later stages or higher levels of desired salinity reduction desalting will play an increasingly important role. The methodology presented and the results or the case study demonstrate the procedures for delineating the magnitudes of either technology's application.

76:05G-025
DESALINIZATION OF A HIGHLY SALINE SOIL, PREDICTION AND FIELD OBSERVATION,
van Hoorn, J.W., Risseeuw, J., and Jurado Prieto, J.M.
Agricultural University, Wageningen, Department of Land and Water Use, Wageningen, The Netherlands
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 558-574. 6 rig, 5 tab, 4 ref.

Descriptors: Desalinization, Saline soils, Hydraulic conductivity, Soil properties, Leaching, Drainage.

On the Marismas soils of the right bank of the Quadalquivir River in Southern Spain an experimental farm was set up to provide detailed information for the future reclamation and development of this area. The desalinization was calculated assuming leaching by rainfall. Since the drains are located on an impermeable layer, the leaching process was calculated by a numerical method assuming a decrease of the amount of percolation water with depth. This desalinization is slower than the one calculated for the drains located well above an impermeable layer, assuming all the water percolating through the soil profile until drain depth.

76:05G-026
ON-FARM WATER MANAGEMENT PRACTICES FOR ALLEVIATING WATERLOGGING AND SALINITY PROB LEMS IN PAKISTAN,
Skogerboe, G.V.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 537-557. 2 fig, 2 tab, 19 ref.

Descriptors: Irrigation, Irrigation effects, Irrigation practices, Salinity, Saline soils, Saline water, Seepage, Irrigation efficiency, Basins.

A modern irrigation conveyance system was constructed in Pakistan during the past 100 years. There are about 38,000 miles of canals and 100,000 tubewells which command a gross area of over 33 million acres of fertile soils. This probably constitutes the greatest single agricultural potential in the world. However, this modern system end at the canal outlet, or 'mogha'. The conveyance of irrigation water from the mogha to the fields is accomplished by unlined watercourses operated and maintained by the farmers with little or no governmental assistance. Previous reports have stated that the conveyance efficiencies of these watercourses are high and that high irrigation application efficiencies can be expected for the basin irrigation method commonly used in the Indus Basin. Recent data have shown watercourse seepage losses to be a significant portion of the water supply, and irrigation application efficiencies are frequently low. Thus, there is a real need for watercourse improvements to save seepage losses and provide better water control in order to achieve higher irrigation application efficiencies. Such improvements would significantly alleviate waterlogging and salinity problems which are a real menace to much of the land.

76:05G-027
EVALUATING IMPROVED IRRIGATION WATER MANAGEMENT TECHNOLOGIES FOR REDUCING SALT PICKUP FROM GRAND VALLEY,
Skogerboe, G.V., Walker, W.R., Evans, R.G., and Smith, S.W.
Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 506-536. 9 fig, 5 tab, 13 ref.

Descriptors: Salinity, Saline soil, Saline water, Irrigation water, Salts, Colorado, Colorado River, Colorado River Basin, Return flow, Irrigation, Irrigation effects, Irrigation practices, Economics.

The problem of increasing salinity levels in the lower stem of the Colorado River has been receiving major attention in recent years because of detriments to both agricultural and urban water users in Southern California and the Republic of Mexico. The Grand Valley in Western Colorado has been identified as a major source of salinity, which is the result of subsurface irrigation return flows which take salts into solution during transport through soils and underlying shales of marine origin. A research program was undertaken in September, 1968, to evaluate appropriate technologies which would reduce subsurface return flows and consequently salt pickup. Canal and lateral lining, irrigation scheduling, improved irrigation methods and practices, and drainage have been evaluated in the field for effectiveness as salinity control measures. Hydrosalinity and soil chemistry modeling are being used to evaluate effectiveness. Cost-effectiveness curves are being developed for each appropriate technology and combinations of technologies. An optimizational format will be used to arrive at the least cost combination for achieving a desired level of salinity control. This analysis will detail the optimal strategy for implementing various levels of individual salinity control measures into a comprehensive technology package.

SECTION XXX

WATER RESOURCES PLANNING

TECHNIQUES OF PLANNING (GROUP 06A)

76:06A-001
METAGAME THEORY AND ITS APPLICATIONS TO WATER RESOURCES,
Hipel, K.W., Ragade, R.K., and Unny, T.E.
Waterloo University, Department of Civil Engineering, Ontario, Canada.
Water Resources Research, Vol. 12, No. 3, p 331-339, June 1976. 14 fig, 4 ref.

Descriptors: *Water resources, *Operations research, *Political aspects, Water pollution control, Management, Behavior, Equations, Feasibility, Decision making, Systems analysis.

Metagame theory is a new scientific method that reconstructs classical game theory on a nonquantitative basis in order to analyze political conflicts. It is a positive descriptive approach that can be used for the political resolution of water resource conflicts. Quantitative methods of operations research may be integrated with the political analysis so as to arrive at solutions to water resource problems that are politically feasible as well as economically and technically feasible. Herein, various resource problems are formulated, and it is shown by two examples that classical game theory, which is based on the theory of rationality, does not work. The concepts of metagame theory are surveyed within a nonquantitative set theoretic framework. The conflicts examined illustrate the potential of metagame theory for analyzing water resource management problems.

76:06A-002
INVESTMENT SEQUENCING, ALLOCATION, AND LEARNING IN THE DESIGN OF WATER RESOURCES SYSTEMS: AN EMPIRICAL APPLICATION,
Rausser, G.C., and Willis, C.E.
Harvard University, Graduate School of Business Administration, Boston, Massachusetts.
Water Resources Research, Vol. 12, No. 3, p 317-330, June 1976. 2 fig, 5 tab, 35 ref.

Descriptors: Water resources, *Design, *Investment, *Water allocation (Policy), Technology, Desalination, Costs, Decision making, Constraints, *California, Computers, Water supply, Water demand, Regional analysis, Estimation, Optimization, Equations, Mathematical models, Systems analysis, Water quality, *Cost allocation.

Four of the more important unresolved problems in the design of water resources systems involve a determination of methods to deal with technological progress (e.g., new desalting processes), availability of water from more than a single supply source, the rate of investment in the capital complex employed to exploit the resource along with the allocation of water once the capital complex is in place, and price sensitive demands for water. The importance of these issues is demonstrated, and a decision framework is advanced which formally incorporates each along with a new technique for solving large-scale investment-sequencing and water allocation problems. The allocation process is formulated as a quadratic programming problem, and the investment-sequencing process is specified as an integer programming problem. Four theorems are advanced which outline the consistency and convergence properties of this iterative approach. The framework is applied to an empirical situation in California with encouraging results.

76:06A-003
THE USE OF LINEAR PROGRAMMING TECHNIQUES FOR ESTIMATING THE BENEFITS FROM INCREASED ACCURACY OF WATER SUPPLY SYSTEMS,
Moore, J.L., and Armstrong, J.M.
Battelle Memorial Institute, Columbus, Ohio.
Water Resources Research, Vol. 12, No. 4, p 629-639, August 1976. 3 fig, 5 tab, 16 ref.

Descriptors: *Water supply, *Forecasting, *Linear programming, *Irrigation, *Agriculture, *Decision making, Optimization, Estimating, Benefits, Probability, Computer programs, Measurement, Assessment, Crops, Economics, Income methodology, Mathematical models, Systems analysis, Risks.

Probabilistic linear programming techniques and Bayesian statistics are combined in this paper by utilizing an example from the area of irrigated agriculture and water supply forecasts to assess the value of increased forecast accuracy to decision units. The case studied was confined to a two-period analysis involving (1) a crop planning period and (2) a growing and harvesting period. The model is developed in terms of Bayesian analysis and demonstrates how linear programming can be applied to rather complex decision making problems involving uncertainty. Testing of the model involved the use of an IBM computer program available at the University of Michigan. For various assumptions as to supplemental water supply, the model showed a net benefit to irrigators of about $6/acre for a reduction in uncertainty of 33% resulting from the introduction and improvement of water supply forecasts.

76:06A-004
ESTIMATION OF RESPONSE SURFACE GRADIENTS IN MULTIOBJECTIVE WATER RESOURCES PLANNING,
McBean, E.A., and Schaake, J.C. Jr.
Waterloo University, Ontario, Canada.
Water Resources Research, Vol. 12, No. 4, p 592-598, August 1976. 8 fig, 15 ref.

Descriptors: *Water resources, *Planning, *Estimating, *Markov processes, *Probability, *Simulation analysis, Methodology, Riverbasins, Reservoirs, Decision making, Comprehensive planning, Alternative planning, Computer models, Hydrology, Irrigation, Mathemetical models, Equations, Systems analysis.

A probabilistic Markov model of reservoir state transistions is developed which, in combination with a simulation model, offers a computational tool for estimating response surface gradients of water resources planning problems. Use of the gradient estimation capability provides a substantial improvement in efficiency of the search for improved water resources configurations. The estimation capability arises by recognizing and using the reservoir state transition changes that would result from a modification of decision variables. The procedure is highly flexible in that it functions under such complicated situations as multiple-objective environments, nonlinear benefit loss functions, and complex connectivity of river basin components.

76:06A-005
ECONOMIC UNCERTAINTIES IN WATER RESOURCES PROJECT DESIGN,
Szidarovsky, F., Bogardi, I., Duckstein, L., and Davis, D.
Eotovs Lorand University, Budapest, Hungary.
Water Resources Research, Vol. 12, No. 4, p 573-580, August 1976. 3 fig, 4 tab, 21 ref, 1 append.

Descriptors: *Water resources, *Projects, *Design, *Economics, Decision making, Equations, Simulation analysis, Monte Carlo methods, Methodology, Systems analysis, Hydrologic costs, Benefits, Height, Optimization, Mathematical models, Risks.

Economic uncertainty programming (Ecup) is a method which enables decision makers to analyze economic uncertainties separately from hydrologic uncertainties in the design of water resources systems. Ecup distinguishes between economic and hydrologic variables in the expression of a payoff or objective function. The economic variables, assumed to have been estimated at discrete points only, are treated as random variables. A postulated joint probability distribution of these variables is used to estimate by Monte Carlo simulation the distribution of payoff resulting from a project. The worth of perfect information or expected opportunity loss is calculated. In a case study, the problem of choosing among flood protection levees of different heights is examined. The random economic factors considered are the flood losses and construction costs. The sensitivity to various degrees of error correlation and loss uncertainty in the economic estimates of the payoff function may cause considerable variance in both the distribution of benefits to be expected from a levee and the height of the optimal levee.

76:06A-006
RELIABILITY, TRADE-OFFS, AND WATER RESOURCES DEVELOPMENT MODELING WITH MULTIPLE CROPS,
Dudley, N.J., Reklis, D.M., and Burt, O.R.
New South Wales University, School of Economics, Kensington, Australia.
Water Resources Research, Vol. 12, No. 6, p 1101-1108, December 1976. 5 fig, 1 tab, 11 ref.

Descriptors: *Irrigation efficiency, *Water resources development, *Water management (Applied), *Planning, *Optimization, *Economic efficiency, *Decision making, *Reliability, Downstream, Crops, Water supply, Benefits, Summer, Inflow, Water utilization, Linear programming, Dynamic programming, Simulation analysis, Reservoir storage, Reservoir releases, Water allocation (Policy), Montana, Design, Estimating, Equations, Mathematical models, Computer models, Systems analysis.

A hierarchy of models, structured to maximize expected benefits, is developed to aid management and planning decisions in multicrop water resources systems located in higher latitudes of the world and featuring significant downstream requirements. A major objective is to quantify tradeoffs between systems with a high reliability of water supply but low average benefits and those of low reliability with high average but also highly variable returns. Linear programming is used to select the best crop combinations for given quantities of water available over the summer, associated water usage, and revenue estimates. A simulation model predicts changes in reservoir storage resulting from inflows and releases to meet requirements of crops selected by the linear program. Interseasonal water allocation is then optimized by using dynamic programming. A method is presented for determining variance of benefits as a function of system design parameters and downstream requiremnts. In an application to a water resources system in Montana, downstream water requirements and penalties were found to have a large effect on high reliability-low reliability tradeoffs. With zero downstream water requirements, there was not tradeoff between expected benefits and variance of benefits as acreage developed for irrigation increased.

76:06A-007
NATIONAL AND INTERREGIONAL MODELS OF LAND USE, WATER ALLOCATION, SOIL LOSS CONTROL, AND AGRICULTURAL POLICY,
Nicol, K.J., Heady, E.O., and Wade, J.C.
Iowa State University, Center for Agricultural and Rural Development, Department of Economics, Ames, Iowa.
Transactions of the American Society of Agricultural Engineers, Soil and Water, p 90-96, Special Edition 1976. 3 fig, 6 tab, 5 ref.

Descriptors: Model studies, Crop production, Agriculture, Simulation analysis, Economics.

National models of agriculture are useful tools to evaluate policy alternatives affecting the agricultural sector and other sectors of the economy that interact with agriculture. This model allows for the analysis of environmental policy and its impacts on agriculture. Regional shifts in production result as the maximum allowable level of gross field loss of soil is reduced to 11,200 kg/ha. Shifts in farming method, inputs, and machinery compliments are needed to facilitate this reduction in soil loss. Different stages of research and analysis being built on a given family of models are presented. The progress reported does not represent a terminal point in this model development. Additional stages are being developed, and the general model will be extended to include further specifications of land and water use, agricultural technology, environmantal impacts, export potential, and farm policies as these relate to farm income, rural employment, consumer food costs, environmental quality, and other social and physical variables.

76:06A-008
QUANTIFYING SOCIETAL GOALS: DEVELOPMENT OF A WEIGHTING METHODOLOGY,
Gum, R.L., Roefs, T.G., and Kimball, D.B.
Arizona University, Economic Research Service, United States Department of Agriculture at Department of Agricultural Economics, Tucson, Arizona 85721
Water Resources Research, Vol. 12, No. 4, p 617-622, August 1976. 3 fig, 1 tab, 24 ref.

Descriptors: Aesthetics, Economics, Recreation, Arizona, New Mexico, Decision making, Planning, Social values, Social needs.

The basic structure of the Techcom planning methodology is reviewed. In the context of this system a weighting methodology is developed to measure preferences regarding the attainment of postulated societal goals. The selected methodology, the Metfessel general allocation test, is applied to the heirarchies of three Techcom goals relating to aesthetics, economics, and recreation. The weighting methodology is tested with answers to a main questionnaire randomly distributed throughout Arizona and New Mexico. Examples of the resulting preference weights are presented, and the use of such measures by decision makers discussed.

76:06A-009
NONPOINT SOURCES: STATE-OF-THE-ART OVERVIEW,
Sweeten, J.M. and Reddell, D.L.
Texas A and M University, Department of Agricultural Engineering, College Station, Texas.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 40 p, 4 fig, 4 tab, 62 ref.

Descriptors: Pollutants, Pollution abatements, Sediments, Nutrients, Pesticides, Sediment transport.

The state-of-the-art in nonpoint source pollution abatement was reviewed and found it to be quite good. A considerable volume of research has been published in the last three decades on singular aspects of what has lately become known as nonpoint source pollution. This basic and applied research has dealt with such classical soil and water conservation topics as erosion control, sediment transport, soil chemistry and physics, crop production, range management, agricultural chemicals, animal science and forestry. The challenge before agricultural engineers today is to work aggressively with agricultural scientists of other disciplines to locate, interpret, adapt and compile this knowledge into forms that can be useful to Section 208 area-wide water quality management planners with nontechnical and/or nonagricultural backgrounds. Fulfillment of this urgent task may constitute the greatest single agricultural engineering contribution of this decade.

76:06A-010
PLANNING A LARGE IRRIGATION PROJECT,
Mahamud, Z.
Rainbow Manufacturing Company, Fitzgerald, Georgia
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 10 p, 8 fig, 1 tab.

Descriptors: Irrigation, Irrigation design, Irrigation effects, Irrigation engineering, Irrigation systems, Project feasibility, Porject planning, Projects.

A complete turnkey project of soil classification, agronomic evaluation with irrigation and drainage study was carried out. Economic analysis with various alternatives was computed.

76:06A-011
PLANNING FOR IMPLEMENTATION UNDER SECTION 208,
Lienesch, W.C. and Emison, G.A.
United States Environmental Protection Agency, Washington, D.C.
Journal of the Water Resources Planning and Management Division, Vol. 102, No. WR2, p 283-295, November 1976. 1 tab, 3 ref.

Descriptors: Water quality, Water quality control, Water quality standards, Water resources, Water pollution, Water pollution control, Return flow, Planning.

Experience with the development of 208 plans has been limited. With the recent increase in the number of agencies developing these plans, more information will soon become available. This paper has reviewed some of the agencies' experiences to date. Although these agencies are limited in number, some conclusions can be made concerning the direction of areawide water quality management planning. Of the issues that must be faced in plan development, the establishment of a regulatory program may be the most difficult. Conflicts will undoubtedly arise over the type of regulatory controls which are to be included in the plan. Since local action will be necessary to enforce many of the controls, it is imperative that the plan be developed in conjunction with the local governments. State involvement in the regulatory program is also essential because of the state role in both point and nonpoint source control. The regulatory program, if it is to be successful, must be developed with full recognition of the need for intergovernmental cooperation between local, regional, and state levels.

SECTION XXXI

WATER RESOURCES PLANNING

EVALUATION PROCESS (GROUP 06B)

76:06B-001
METARATIONALITY IN BENEFIT-COST ANALYSIS,
Ragade, R.K., Hipel, K.W., and Unny, T.E.
Louisville, University, Systems Science Center, Louisville, Kentucky.
Water Resources Research, Vol. 12, No. 5, p 1069-1076, October 1976. 8 tab, 10 ref.

Descriptors: *Water resources, *Management, *Methodology, *Cost-benefit analysis, Optimization, River basin development, Fishing, Projects, Decision making, Equations, Mathematical models, Systems analysis.

In water resources management, intangibles and multiple decision criteria exist as a result of various multipurpose needs. This paper presents a type of benefit-cost analysis which is capable of handling both quantitative and intangible benefits and costs. Using this methodology, it is possible for each interest group to assign values to benefits and costs according to what the group thinks is correct. Linguistic descriptions are sufficient for the intangibles. The method is based upon the theory of metarationality, and it is shown how pseudo-Boolean functions can be used to define the concepts of metarationality and also to record preferences of the parties involved in an analysis. In an example, the preferences of two nations involved in a fishing dispute are recorded using the pseudo-Boolean functions. The methodology is applied to a hypothetical river basin problem.

76:06B-002
RESOURCE ADEQUACY IN LIMITING NONPOINT POLLUTION,
Heady, E.O.
Iowa State University, Ames, Iowa.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 16 p, 3 fig, 6 tab, 2 ref.

Descriptors: Computer programs, Model studies, Computer models, Runoff, Sedimentation, Economics.

A national programming model of 105 regions, 41 water supply regions and 9 land groups per region is used to evaluate potentials in reducing nonpoint pollution through control of runoff and sedimentation. Evaluation of economic outcomes also is made for alternatives specified to enhance environmental quality.

76:06B-003
AN ANALYSIS OF AGRICULTURAL WATER REQUIREMENTS IN THE TAR-NEUSE RIVER BASIN OF NORTH CAROLINA,
Sowell, R.S., Sneed, R.E., and Chen, L.H.
North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, North Carolina
Presented at the 1976 Winder Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 18 p, 6 fig, 5 tab, 8 ref.

Descriptors: Irrigation, Irrigation effects, North Carolina, Computer models, Crop production, Irrigation water.

A study of agricultural water requirements in the Tar-Neuse River Basin--a 35 county region--of Eastern North Carolina was made using previously developed computer models. Results show a potential increase in net return of up to 34% when crops are grown under irrigation vs. no irrigation.

76:06B-004

OPTIMIZATION OF WATER USE FOR IRRIGATION,

Van Deman, J.M., Sowell, R.S., and Sneed, R.E.
North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, North Carolina.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 20 p, 15 tab, 5 equ, 5 ref.

Descriptors: Computer programs, Computer models, Irrigation, Water requirements, Linear Programming, North Carolina, Irrigation water, Crop production, Soils.

A computer system has been developed for determining optimal use of a limited supply of water for the irrigation of crops. The system includes: a computer program which determines water requirements of a particular crop/soil/irrigation policy combination; a linear program; a computer program to reduce data to the input format required by MPS/360; an MPS/360 program for solution of the linear program; and a computer program to reduce the MPS/360 solutions to user oriented output reports. This system was used in a study of optimal water use in a county in eastern North Carolina. Results of the study indicate the potential of increased return from agriculture by optimally using water available for irrigation.

76:06B-005

DRAINAGE PROGRESS AND PROBLEMS ON THE COLUMBIA BASIN PROJECT,

Neumann, C.A.
United States Bureau of Reclamation, Othello, Washington
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, December 14-17, 1976, Chicago, Illinois. 10 p, 5 ref.

Descriptors: Drainage districts, Drainage effects, Drainage practices, Drainage programs, Drains, Columbia River, Drainage engineering, Drainage water.

Construction has been completed for approximately 4,757 kilometers (2,956 miles) of agricultural drains and outlet channels on the Columbia Basin Project. This paper discusses some of the recent advances and problems associated with drain construction on the Project.

SECTION XXXII

WATER RESOURCES PLANNING

COST ALLOCATION, COST SHARING, PRICING/REPAYMENT (GROUP 06C)

76:06C-001
ECONOMIC AND WATER USE IMPACTS ASSOCIATED WITH ALTERNATIVE WATER PRICING POLICIES OF ESTABLISHED IRRIGATION DISTRICTS,
Schmisseur, W.E.
Oregon State University, Department of Agricultural and Resource Economics, Corvallis, Oregon.
Available from the National Technical Information Service, Springfield, Virginia as PB-259 559, Price codes: A05 in paper copy, A01 in microfiche. Oregon Water Resources Research Institute, Corvallis, Completion Report WRRI-47, September 1976. 78 p, 40 tab, 13 ref, append. OWRT A-022-Ore(1).

Descriptors: *Linear Programming, *Irrigation districts, *Pricing, Irrigation, Sprinkler irrigation, *Alternative costs, Model studies, *Oregon, Water policy, *Alternative water use, *Economic impact, *Water costs.

A linear programming model of two diverse, operating irrigation districts in Oregon is used to identify technical and economic effects attributed to fixed cost, base allotment, and responsive water pricing. From this district specific analysis general guidelines are developed relative to water pricing policies and their impacts. Water diversion and peak use were greater with fixed cost pricing than with either base allotment or responsive pricing. For base water allotment pricing to be effective in rationing water use however, the base allotment should be set at a level where variable charges come into play and these charges must be high enough to moderate water use. Relative to fixed cost pricing water costs were appreciably increased and crop returns were reduced with either base allotment or responsive water pricing. With either of these pricing schemes, the highest water cost and greatest reduction in crop returns on an irrigated acre basis were borne by the less water and yield efficient farms. Relative to base allotment pricing, net water revenues of the district were greater with responsive pricing. The smallest range in water cost either on an irrigated acre or acre foot gasis occurred with responsive pricing. The smallest range in water cost either on an irrigated acre or avre foot basis occurred with responsive pricing.

76:06C-002
CONSERVATIONAL WATER PRICING FOR INCREASED WATER SUPPLY BENEFITS,
Carey, D.I., and Haan, C.T.
Kentucky University, Department of Agricultural Engineering, Lexington, Kentucky.
Water Resources Bulletin, Vol. 12, No. 6, p 1119-1131, December 1976. 4 fig, 2 tab, 8 ref.

Descriptors: Pricing, Water conservation, Water supply, Water supply developments, Water costs, Water management, Water resources development, Water utilization, Water.

A study was undertaken to see if benefits from water supply could be increased by utilizing price-usage information in reservoir design studies. Three pricing policies were examined. The first policy assumed no price-use relationship, and quantity demanded was based on existing community usage with a low water rate. The price of water was set to recover system costs. A price-use relationship was assumed in the second policy and the water rate was constant. The price of water was determined from the associated system which provided maximum expected net benefits. The third policy assumed the price-use relationship and the price charged for water during each billing period was a non-linear function of storage which increased as the amount of water in storage at the beginning of the period decreased. It was found that the use of the conservation pricing policies substantially reduced storage requirements while providing demonstrable net benefits to the community and a large average supply. The conservation pricing policies substantially lowered the average price paid for water. The effect of uncertainty in consumer response to changes in price was studied by using a probabilistic price-use relationship. This uncertainty did not significantly reduce the effectiveness of the conservation policy. It was concluded that demand management by the use of a proper pricing policy could significantly increase net water supply benefits to a community.

76:06C-003
THE USE OF CROSSOVER DISCOUNT RATES IN IRRIGATION SCHEME DESIGN,
Nudds, D., and Bottomley, A.
Bradford University, Department of Economics, Bradford, Yorkshire, England.
Water Resources Bulletin, Vol. 12, No. 2, p 277-280, April 1976. 1 fig, 1 tab.

Descriptors: Irrigation, Discount rates, Economics, Irrigation systems, Capital cost, Interest rate.

Present values of costs on different scheme designs vary with the rate of discount chosen. One design may yield a higher present cost at a particular rate of discount and a lower present cost at another rate. Choice of scheme design will, therefore, depend upon the rate of discount thought to equal to opportunity cost of capital in the nation contemplating the project. The design with the highest internal rate of return is not necessarily the one which should in all cases be selected.

SECTION XXXIII

WATER RESOURCES PLANNING

WATER DEMAND (GROUP 06D)

76:06D-001
THE DEVELOPMENT OF WATER MULTIPLIER IMPACTS FROM INPUT-OUTPUT ANALYSIS: AN EMPIRICAL EXAMPLE FROM BOULDER, LARIMER, AND WELD COUNTIES, COLORADO,
Gray, S.L., and McKean, J.R.
Colorado State University, Department of Economics, Fort Collins, Colorado.
Water Resources Research, Vol. 12, No. 2, p 135-140, April 1976. 7 tab, 10 ref.

Descriptors: *Water utilization, *Input-output analysis, *Leontief models, *Economics, Estimating, Water demand, Planning, Water supply, Equations, Mathematical models, Systems analysis, *Colorado.

The relationship between economic activity in a regional economy and water intake and consumptive use requirements is investigated by using the Leontief model. Estimates of direct and indirect water requirements for the regional economy are developed and are applied to three distinct planning questions: estimated aggregate water use in the regional economy, estimated sector by sector water requirements in response to total projected changes in final demands, and estimated changes in water requirements in the regional economy given a change in a single sector's deliveries to final demand.

76:06D-002
OPTIMAL ON-FARM ALLOCATION OF IRRIGATION WATER,
Trava, J., Heermann, D.F., and Labadie, J.W.
Colegio de Post Graduados, Department of Agricultural Engineering, Chapingo, Mexico.
Paper No. 76-2040, Presented at the 1976 Annual Meeting of the American Society of Agricultural Engineers, June 27-30, 1976, Lincoln, Nebraska 14 p, 4 tab, 23 ref.

Descriptors: Model studies, Simulation analysis, Irrigation water, Crop production, Optimization, Systems analysis, Water allocation, Water delivery.

The USDA-ARS Scheduling Program is a powerful tool to assist management in the efficient use of irrigation water on the farm. The Water Management Program incorporating an optimization technique provides a tool for scheduling irrigation within constraints of water and labor. The application of systems analysis in making operational real-time management decisions has far-reaching possibilities for further development. More complex objective functions and additional constraints will provide even more assistance to management. The application of the Dantzig-Wolfe decomposition principle to large-scale water management problems demonstrates a feasible way of using systems analysis for operational problems.

SECTION XXXIV

WATER RESOURCES PLANNING

WATER LAW AND INSTITUTIONS (GROUP 06E)

76:06E-001
AGRICULTURAL LEGISLATION'S POTENTIAL IN REDUCING DISCHARGE OF POLLUTANTS,
Gambell, E.L.
United States Department of Agriculture, Program Analysis, Environmental Quality
and Land Use Staff, Agricultural Stabilization and Conservation Service,
Washington, D.C.
Water Resources Bulletin, Vol. 12, No. 6, p 1171-1179, December 1976. 12 ref.

Descriptors: Agriculture, Pollution abatement, Legal aspects, Legislation, Agricultural runoff, Return flow, Water quality.

Agricultural lands (including most forest lands) make up almost four-fifths of the total land area of the United States and include, or are traversed by, perhaps an equal proportion of our ground and surface waters. Therefore, a very large part of our environment is directly 'agriculture-related' in any consideration of the discharge of pollutants. Several important Federal and State laws relate to the control or abatement of agriculture-related pollution. Existing legislation generally mandates the control or abatement of pollution (from point or nonpoint sources) or authorizes the use of public funds or other resources for such purposes. Some of these laws can be effective instruments in keeping pollutants from being discharged into surface or ground waters or into the air, but the degree to which som pollutants originating from agricultural lands and operations constitute a serious environmental hazard in waters remaining controversial. Although most of the technology exists to reduce greatly the movement of these pollutants, investments are often required which benefit the nonfarm public without economic returns to the farmer. Whether a zero discharge is either an environmentally or economically feasible alternative to more limited or selective control, is explored. However, if the public is willing to bear its reasonable share of the cost for clear air and water, the needed basic legislation already largely exists. Under it, agricultural land holders may apply program standards and use their own and available program resources to bring about effective control or abatement of pollutants.

76:06E-002
INSTITUTIONAL PROBLEMS OF ENERGY PRODUCTION,
Trelease, F.J. III
Wyoming Water Planning Program, State Engineer's Office, Cheyenne, Wyoming 82001
Water Resources Bulletin, Vol. 12, No. 5, p 931-939, October 1976. 2 fig, 2 tab, 3 ref.

Descriptors: Institutional constraints, Institutions, Planning, Permits, Energy, Oil shale, Wyoming, Coals, Water resources.

The Rocky Mountain and Great Plains Regions of the West have recently come into focus as a fuel source for an energy hungry nation. Development of energy resources will require compliance with, or regulation under many established 'institutions'. New institutions, such as plant siting permits and tougher environmental and land use controls are being established. A year ago the nation seemed to be moving rapidly towards Project Independence--achieving national self-sufficiency in energy production. Now there appears to be several factors that are combining to impede the energy development, and these include national, regional, and local policies, problems associated with financing, environmental concerns, and reluctance to change (or be impacted by development). The institution of the courts has even come into paly. Western coal, oil shale, and uranium resources will require water to convert them into usable forms of energy. This is true whether the resources are converted into fuel or electricity at the mine sites or elsewhere. Western water law and a broad background of water development experience should pave the way for providing the water necessary for development of the energy minerals. On the other hand, the water institutions may be formed in ways or may be utilized in ways to create another impediment to energy development. Wyoming water resources and water law will be discussed in this paper as an example.

76:06E-003
PROCEEDINGS OF THE CONFERENCE ON SALT AND SALINITY MANAGEMENT,
California University, Davis, California 95616
Proceedings of the Conference held at Santa Barbara, California, September 23-24, 1976, Report # 38, December 1976. 166 p

Descriptors: *Salts, *Salinity, *Water management, *Water quality control, *Legislation, *Political aspects, *Institutions, Irrigation, Waste water disposal, California, Operations, Technology, Soil tolerance, Water utilization.
(see 76:05G-020)

SECTION XXXV

WATER RESOURCES PLANNING

NONSTRUCTURAL ALTERNATIVES (GROUP 06F)

76:06F-001
LAW, HYDROLOGY, AND SURFACE-WATER SUPPLY IN THE UPPER COLORADO RIVER BASIN,
Jacoby, G.C. Jr., Weatherford, G.D., Wegner, J.W.
Lamont-Doherty Geological Observatory, Palisades, New York.
Water Resources Bulletin, Vol. 12, No. 5, p 973-984, October 1976. 4 fig, 24 ref.

Descriptors: *Colorado River Basin, *Water resources development, *Colorado River Compact, *Water law, Legal aspects, Hydrology, Water supply, Surface waters, River basin development, Water resources, Water Allocation (Policy), Water demand, Streamflow, Water policy, Groundwater, Boulder Canyon Project Act, Colorado River, Dendrochronology.

The relationship between law and hydrology in water resources development is discussed. Law attempts to allocate a limited and valuable resource while hydrology tries to define the limits of the resource. In the past an inadequate data base has made hydrologic estimates difficult and political factors pushed the law into possibly conflicting commitments in the Colorado River Basin. The water allocation process and the role of hydrology in defining the risk of deficiency are described and a historical overview of the interaction between law and hydrology is presented. Using tree-ring research, hydrologists have produced a more definite data base and thus given legal policy makers more reliable information. As development approaches the resource limit in the Upper Colorado River Basin, lawyers and hydrologists must act in concert toward the equitable solution of allocation and reallocation problems.

SECTION XXXVI

RESOURCES DATA

DATA ACQUISITION (GROUP 07B)

76:07B-001
CORRECTION OF "TUBE CONTRIBUTION" INTERFERENCE IN THE DETERMINATION OF HEAVY METALS BY X-RAY SPECTROSCOPY USING THE "ADDITIONS TECHNIQUE",
Keramidas, V.Z., and Fanning, D.S.
Maryland Agricultural Experiment Station, Department of Soil Science, College Park, Maryland.
Soil Science Society of America Journal, Vol. 40, No. 6, p 857-860, November-December 1976. 2 fig, 1 tab, 7 ref.

Descriptors: *Heavy metals, Zinc, Copper, Nickel, Soil chemistry, Soil properties, Soil investigations, X-ray spectroscopy.

Cr and W X-ray tubes emitted not only the target characteristic lines but the lines of Fe, Zn, Cu, and Ni as well. Such extraneous radiation, which probably originates primarily from contamination of the tube target by the metals and is referred to as "tube contribution," may lead to erroneous qualitative interpretation of X-ray spectra because peaks of the elements may appear in the spectra when the element is not present in the sample. The additions (or spiking) technique allows matrix problems to be overcome in the quantitative measurement of Zn, Cu, and Ni in soil and other materials, but an accurate estimation of the background under the peak is essential.

76:07B-002
A SEMIAUTOMATED PROCEDURE FOR TOTAL NITROGEN IN PLANT AND SOIL SAMPLES,
Gallaher, R.N., Weldon, C.O., and Boswell, F.C.
Florida University, Department of Agronomy, Gainesville, Florida.
Soil Science Society of America Journal, Vol. 40, No. 6, p 887-889, November-December 1976. 2 fig, 1 tab, 12 ref.

Descriptors: *Nitrogen, Laboratory tests, Laboratories, Soil investigations, Soil properties.

This study evaluated inexpensive alternatives for the determination of total N in plant and soil samples. Plant and soil samples which varied widely in N concentration were digested in a 126-sample-capacity Al block digester followed by determination of total N with the ammonium electrode in a semiautomated reaction vessel assembly. The proposed Ammonium electrode semiautomated (AES) procedure was compared to standard micro-Kjeldahl and aluminum block digested-steam distilled-titrated (ABDDT) procedures. Thirty to 50 more samples could be analyzed per 8-hour day with the proposed simiautomated procedure as compared to standard micro-Kjeldahl methods. The precision of the methods were comparable but significantly more N was found by using the ABDDT procedure.

76:07B-003
ESTIMATING WATER SALINITY WITH GEOPHYSICAL EARTH RESISTIVITY EQUIPMENT,
Halvorson, A.D., and Reule, C.A.
United States Department of Agriculture, Agricultural Research Service, Western Region, P.O. Box 1109, Sidney, Montana.
Soil Science Society of America Journal, Vol. 40, No. 1, p 152-153, January-February 1976. 2 fig, 1 tab, 5 ref.

Descriptors: *Salinity, *Salts, Laboratory tests, Soil salinity, Water salinity.

A procedure is described for estimating salinity of water samples in the field using a geophysical earth resistivity meter and four-electrode conductivity cell. Using field collected water samples, a linear relationship of $Y = 1.02(X) + 0.12$, $r = 0.996$, was obtained between Electro conductivity at 25 degrees centigrade values determined using a commercial laboratory bridge and cell (Y), and those determined using an earth resistivity meter and an easily fabricated, four-electrode conductivity cell (X).

76:07B-004
A METHOD FOR SECTIONING SATURATED SOIL CORES,
Reddy, K.R., and Patrick, W.H. Jr.
Louisiana State University, Department of Agronomy, Baton Rouge, Louisiana.
Soil Science Society of America Journal, Vol. 40, No. 4, p 611-614, July-August 1976. 3 fig, 2 tab, 5 ref.

Descriptors: Laboratory tests, Sampling, Soils, Soil physical properties, Soil investigations, Ions, Cores.

A simple system for sectioning water-saturated cores without prior freezing is described. The method describrd can be used for studying the distribution and movement of ions in soil or sediment cores prepared in the laboratory or obtained in undisturbed form from the field. The average coefficient of variation was 4.8% for the sectioning of the cores prepared in the laboratory and 10.5% for the sectioning of the cores obtained from the field.

76:07B-005
IN SITU MEASUREMENT OF GAS DIFFUSION COEFFICIENT IN SOILS,
Lai, S.H., Tiedje, J.M., and Erickson, E.
Michigan State University, Department of Crop and Soil Sciences, East Lansing, Michigan.
Soil Science Society of America Journal, Vol. 40, No. 1, p 3-6, January-February 1976. 4 fig, 3 tab, 12 ref.

Descriptors: Soils, Soil investigations, Soil profiles, Gas chromatography, Soil properties, Carbon dioxide.

A method for determination of the gas diffusion coefficient of soils without disturbing the natural state of the soil was developed. The method was based on the theory of radial diffusion of a finite quantity of gas into a semi-infinite porous medium. Needles were inserted into the soil through which O2 was injected. The change of concentration of the injected O2 was determined by gas chromatography through the same needle after increasing periods of time. A least square fit between the measured O2 concentrations and that of the theoretical values was conducted to find the best fit value of the diffusion coefficient. The diffusion coefficient determined by the proposed method was used to calculate the flux of CO2 in field soils. The flux so calculated was compared to that measured from the field with good agreement. The method was used in several different field soils and conditions to determine the diffusion coefficients.

76:07B-006
EVALUATION OF METHODS FOR PRESERVING THE LEVELS OF SOLUBLE INORGANIC PHOSPHORUS AND NITROGEN IN UNFILTERED WATER SAMPLES,
Klingaman, E.D., and Nelson, D.W.
Purdue University, Agricultural Experiment Station, Lafayette, Illinois.
Journal of Environmental Quality, Vol. 5, No. 1, p 42-46, January-March 1976. 3 tab, 11 ref.

Descriptors: *Nitrogen, *Phosphorous, *Nitrate, Sampling, Laboratory test, Surface runoff, Drainage water.

Several methods for preserving the levels of soluble inorganic phosphorus (SIP), ammonium, and nitrate in surface runoff, tile drainage water, and river water were evaluated. The best overall technique for preservation of water samples for P and N analysis appeared to be storage at subzero temperatures. The SIP concentration in samples was also stabilized by addition of HgCl2 (40 mg/liter) and storage at 4C; however, the ammonium and nitarte levels in samples were not preserved for long periods of time (12 weeks) by this technique. The soluble inorganic N levels in water samples were preserved by addition of phenylmercuric acetate (20 mg/liter) and storage at 4C, but use of this procedure increased the SIP concentration in some samples during storage. Storage of samples at 4C or 23C without addition of a chemical preservative resulted in large changes in soluble inorganic P and N contents.

75:07B-007
EFFECT OF PRETREATMENT ON LOSS OF NITROGEN-15-LABELLED FERTILIZER NITROGEN FROM WATERLOGGED SOIL DURING INCUBATION,
McKenzie, E. Jr., and Kurtz, L.T.
Prairie View A and M University, Prairie View, Texas.
Soil Science Society of America Journal, Vol. 40, No. 4, p 534-537, July-August 1976. 1 fig, 3 tab, 27 ref.

Descriptors: *Denitrification, *Nitrogen, *Incubation, Soil chemical properties, Soil tests, Soil investigations, Soils, Nutrients.

Soil preparation treatments (field-moist, intact cores; oven dried, intact cores; and oven dried, crushed, screened soil) greatly influenced fertilizer nitrogen loss under waterlogged conditions in the laboratory. Nitrogen (300 pp2m) as N-15-labelled calcium nitrate was added to samples from selected horizons of Drummer silty clay loam and they were subsequently covered with water and incubated for 0, 4, 8, 16, and 32 days. Samples of upper (above 51 cm) soil horizons were incubated at 21C while those from deeper horizons were incubated at 18C. Oven-drying and crushing of the soil during preparation increased fertilizer nitrogen loss. Only 34% of the fertilizer nitrogen disappeared from field-moist, intact soil cores while approximately 90% disappeared from both oven-dried, intact cores and crushed screened samples. Maximum rate of denitrification of fertilizer nitrogen in field-moist, intact cores was 3.58% of the applied nitrogen per day. This rate was approximately one-third of that in the oven-dried, intact cores and one-ninth of that in the oven-dried, crushed samples.

76:07B-008
CATION-EXCHANGE CAPACITY OF ACID SOILS USING ALUMINUM CHLORIDE AND BARIUM CHLORIDE-TRIETHANOLAMINE,
Alexander, E.B.
United States Forest Service, Department of Soil Science.
Soil Science Society of America Journal, Vol. 40, No. 6, p 961-963, November-December 1976. 1 tab, 6 ref.

Descriptors: Laboratory tests, Cation exchange, Soil properties, Soil tests, Soil investigations.

Base saturation is such an important criterion for classifying soils in the U.S. Soil Taxonomy that a procedure has been developed for scantily equipped field laboratories. Exchange acidity and cation-exchange capacity (CEC) are determined in sequence with the same samples. The procedure involves (i) displacement of exchangeable hydrogen and Al with BaCl2-triethanolamine solution and back-titration with HCl to determine the exchange acidity, (ii) saturation with Al from AlCl3 solution, (iii) removal of excess Al with water, (iv) displacement of Al with BaCl2-triethanolamine solution and back-titration with HCl to determine the exchange capacity, and (v) estimation of basic cations by the difference between the CEC and the exchange acidity. This is an extension of a well-established procedure for determining exchange acidity. The CEC results compare closely with the sums of cations for acid subsoils, but are low for Al horizons with much organic matter.

76:07B-009
DETERMINATION OF THE HYDRAULIC CONDUCTIVITY - DRAINABLE POROSITY RATIO FROM WATER TABLE MEASUREMENTS,
Skaggs, R.W.
North Carolina State University, Department of Biological and Agricultural Engineering, Raleigh, North Carolina.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 1, p 73-84, January-February 1976. 13 fig, 25 ref.
(See 76:02F-005)

76:07B-010
A TECHNIQUE TO DETERMINE IRON EFFICIENCY IN PLANTS,
Brown, J.C., and Jones, W.E.
United States Department of Agriculture, Agricultural Research Service, Plant Stress Laboratory, Beltsville, Maryland.
Soil Science Society of America Journal, Vol. 40, No. 3 p 398-405, May-June 1976. 6 fig, 3 tab, 16 ref.

Descriptors: Iron, Crop response, Fertilization, Soil tests, Soil investigations, Nutrients, Crop production.

Soil tests should predict crop response to fertilization. In the case of Fe, plant factors seem to affect the use of Fe by the plant; thus, soil tests may not be reliable. Use of soil Fe by plants is genetically controlled by an adaptive mechanism which is activated in Fe-efficient plants in response to Fe-stress, but remains inactive if Fe is sufficient. Fe-inefficient plants develop less Fe-stress response than Fe-efficient plants. Using this range of Fe-stress response in plants as a basis, we developed a technique to screen plants for Fe efficiency. A limited supply of Fe and some control using nutrient solutions, N only as NO3, and N as NH4 and NO3, and by varying the CaCO3 and P concentrations in the solutions. The optimum supply of Fe (0.2 mg Fe/liter) was determined by growing the plants at different Fe concentrations.

76:07B-011
LINE SOURCE SPRINKLER FOR CONTINUOUS VARIABLE IRRIGATION-CROP PRODUCTION STUDIES,
Hanks, R.J., Keller, J., Rasmussen, V.P., and Wilson, G.D.
Utah State University, Department of Soil Science, Logan, Utah.
Soil Science Society of America Journal, Vol. 40, No. 3, p 426-429, May-June 1976. 3 fig, 2 tab, 4 ref.

Descriptors: *Sprinkler irrigation, Irrigation, Irrigation systems, Irrigation effects, Crop production, Crop response, Fertilization.

The design details and a sample set of field test results for a line source sprinkler plot irrigation system are presented. The system produces a water application pattern which is uniform along the length of the plot and continuously, but uniformly variable across the plot. By applying a fertility variable along a plot (at right angles to the water variable) planted in some test crop, the system offers a convenient means for developing crop production function data. The system test area and water supply are both small. However, the application of the system may be limited by wind and all water application levels within a plot must be supplied at the same irrigation frequency.

76:-7B-012
SOIL SOLUTION CONCENTRATIONS: EFFECT OF EXTRACTION TIME USING POROUS CERAMIC CUPS UNDER CONSTANT TENSION,
Severson, R.C., and Grigal, D.F.
United States Geological Survey, Department of Soil Science, Denver, Colorado.
Water Resources Bulletin, Vol. 12, No. 6, p 1161-1170, December 1976. 4 fig, 2 tab, 12 ref.

Descriptors: Soil water, Potassium, Calcium, Phosphorus, Moisture tension, Soil moisture, Lysimeters, Soil investigations, Laboratory studies.

Proous ceramic cups under constant tension (0.45 bar) were used to extract solutions from undisturbed soil columns. Solution concentration changed with length of extraction time. Significant relationships were found between extraction time and concentrations of P, Ca, and K in soil solution for two sample depths in an Omega loamy sand soil column. At two extraction time classes and at two sample depths, combined data from 12 soil columns representing two soil series reinforce the relationship. As time to extract a sample increases, the sample probably represents solution held by soil at tensions approaching those applied to the ceramic cup. We recommend that the choice of an extraction tension be given consideration in studies using porous ceramic cups under constant tension for monitoring constituents of soil solution. In addition, care must be taken to attain good physical contact between the cups and the soil material.

76:07B-013

EVALUATION OF RESITANCE AND MASS TRANSPORT EVAPOTRANSPIRATION MODELS REQUIRING CANOPY TEMPERATURE DATA,

Blad, B.L., and Rosenberg, N.J.

Nebraska University, Institute of Agriculture and Natural Resources, Agricultural Meteorology Section, Department of Agricultural Engineering, Lincoln, Nebraska.

Agronomy Journal, Vol. 68, No. 5, p 764-769, September-October 1976. 9 fig, 19 ref.

Descriptors: Alfalfa, Satellites, Canopy, Temperature, Evapotranspiration, Hydrology, Water management, Model studies, Subsurface irrigation, Remote sensing, Advection.

The increasing use of thermal scanners on aircraft and satellites makes it likely that data on surface temperature for large areas will become routinely available. If reliable evapotranspiration methods which incorporate surface temperature data can be developed, an important tool for research and application in hydrology, in irrigation scheduling, and in other water management procedures will result. A 'resistance model' which stems from the work of Brown and Rosenberg and a mass transport (Daltonian) model for estimating evapotranspiration (ET) were tested on large fields of naturally subirrigated alfalfa. Both models make use of crop canopy temperature data. Temperature data were obtained with an IR thermometer and with leaf thermocouples. A Bowen ratio-energy balance (BREB) model, adjusted to account for underestimation of ET during periods of strong sensible heat advection, was used as the standard against which the resistance and mass transport model did not agree quite as well. Performance was good on clear and cloudy days and also during periods of nonadvection of sensible heat. The performance of the mass transport and resistance models was less satisfactory for estimation of fluxes of latent heat for short term (15 min) periods. Both models tended to overestimate at low LE fluxes.

76:07B-014

PERFORMANCE OF THE SILVER-PSYCHROMETER FOR MEASURING LEAF WATER POTENTIAL IN SITU,

Hoffman, G.J., and Hall, A.E.

Western Region, Agricultural Research Service, United States Department of Agriculture, P.O. Box 672, Riverside, California 92502

Agronomy Journal, Vol. 68, No. 6, p 872-875, November-December 1976. 4 fig, 17 ref.

Descriptors: Moisture stress, Temperature, Humidity, Radiation, Soil moisture, Soil water.

Continuous in situ measurements of leaf water potential are often needed in studies of the soil-plant-atmosphere continuum. The development of the silver-foil thermocouple psychrometer has made these measurements possible. The objective of the investigation was to evaluate the performance of the silver-foil psychrometer under various steady-state and dynamic conditions. Leaf water potential measurements were made in situ on pinto bean in a controlled environment plant chamber where temperature, relative humidity, CO_2 concentration, radiation, and photoperiod were precisely controlled. Typically, the psychrometer will reach equilibrium with an intact leaf 2 hours after attachment. Consistent leaf water potentials are attainable when the leaf temperature varies by as much as 0.25 C/min. This thermal stability is as good as that of any multijunction psychrometer described to date. At radiation levels below 50 Wm(-2), leaf water potential readings can be made on unshaded leaves; above this level, the leaf must be shaded to prevent thermal gradients across the leaf and psychrometer. The silver foil psychrometer responded to rapid oscillations in leaf water potential. During oscillations, leaf water potential preceded leaf conductance and transpiration by one-third of the oscillation period. Net photosynthesis oscillated in phase with leaf conductance, indicating that net photosynthesis is limited by the internal CO_2 concentration, even at very low irradiances.

76:07B-015
SAMPLING THE UNSATURATED ZONE IN IRRIGATED FIELD PLOTS,
Pratt, P.F., Warneke, J.E., and Nash, P.A.
California University, Department of Soil Science, Riverside, California 92502.
Soil Science Society of America Journal, Vol. 40, No. 2, p 277-279, March-April 1976. 6 tab, 7 ref.

Descriptors: Nitrate, Chloride, Drainage water, Salinity, Electrical conductance, Farm waste, Soils, Soil investigations, Irrigation, Irrigation effects, Sampling.

Data obtained from samples from each of 10 holes/plot for one plot from each of three soils were subjected to statistical analysis and used to formulate plans for sampling the 1.5- to 4.5-cm depth of 48 experimental plots that had received animal manures. The statistical analysis of these three plots suggested that 10 holes/plot and 10 samples/hole would provide plot means within about 20 percent of the true means for nitrate and chloride concentrations and electrical conductivity of saturation extracts, except for one soil which had residual salts in highly variable concentrations at the 3.0- to 4.5-cm depth. The sampling procedure developed gave satisfactory results when statistical analysis of the effects of manure treatments, soils and irrigation levels on nitrate, chloride and EC(e) were measured.

76:07B-016
EXTENDED FIELD USE OF SCREEN-COVERED THERMOCOUPLE PSYCHROMETERS,
Brown, R.W. and Johnston, R.S.
United States Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah 84401
Agronomy Journal, Vol. 68, No. 6, p 995-996, November-December 1976. 1 fig, 1 tab, 7 ref.

Descriptors: Soil water, Soil moisture, Data collection.

The use of screen-covered thermocouple psychrometers for insitu measurements of soil water potential has been criticized because of possible soil and micro-organism contamination through the screen covering. Double-junction Peltier psychrometers with a screen covering were installed in the soil under field conditions for periods ranging from 2 to 40 months of continuous exposure, and were then removed and examined for evidence of loss of calibration sensitivity and contamination by soil particles and micro-organisms. The uncleaned psychrometers were recalibrated in the laboratory and then disassembled and examined under a microscope (250 times) for contamination. Although slightly more than half of the units lost some sensitivity after field exposure, the average decrease was less than 5%. The psychrometer cavities were all nearly free of soil particles, the thermocouple junctions were shiny, and no evidence of microbial attack was evident. It appears that long-term field exposure of screen-covered psychrometers is no more detrimental to their performance than that of ceramic or other psychrometers.

76:07B-017
ALGORITHM FOR SOLAR RADIATION ON MOUNTAIN SLOPES,
Swift, L.W. Jr.
United States Department of Agriculture, Coweeta Hydrologic Laboratory, Southeastern Forest Experiment Station, Forest Service, Franklin, North Carolina 28734
Water Resources Research, Vol. 12, No. 1, p 108-112, February 1976. 2 fig, 1 tab, 17 ref.

Descriptors: Algorithms, Solar radiation, Computer models, Model studies, Mountains.

A generalized algorithm provides the daily total of potential solar radiation on any sloping surface at any latitude. The algorithm can be coded as subroutines of a computer model that requires solar radiation as a variable. The required inputs are Julian dates and the latitude, inclination, and aspect of the slope. In addition to computing potential solar radiation, the routine provides estimates of actual radiation on any slope on the basis of measured solar radiation for a nearby horizontal surface that has the same cloud cover.

76:07B-018

NEW TECHNIQUE FOR MEASURING THE WATER POTENTIAL OF DETACHED LEAF SAMPLES,

United States Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah 84401
Agronomy Journal, Vol. 68, No. 2, p 432-434, March-April 1976. 4 fig, 7 ref.

Descriptors: Evaporation, Sampling, Leaves.

Evaporative losses and contamination in sample disks after they are cut from plant leaves often cause errors in measurements of water potential. A new technique for collecting detached leaf disks to measure water potential eliminates most of the errors associated with other methods. The leaf cutter contains a double-junction Peltier thermocouple psychometer. When a leaf disk is removed from the plant, it can be sealed immediately against the cavity containing the psychometer.

76:07B-019

EVALUATION OF AN ELECTRONIC FOLIOMETER TO MEASURE LEAF AREA IN CORN AND SOYBEANS,

Hatfield, J.L., Stanley, C.D., and Carlson, R.E.
California University, Atmospheric Sciences Section, Department of Land, Air, and Water Resources, Davis, California 95616
Agronomy Journal, Vol. 68, No. 2, p 434-436, March-April 1976. 2 fig, 1 tab, 5 ref.

Descriptors: Corn, Soybeans, Measurement.

Known areas were measured with an electronic foliometer to determine the errors involved with this instrument. Good agreement between measured and known areas was found and there was high accuracy and precision for both the conveyor belt and sheath method. Thests were made comparing the foliometer, a planimeter, and maximum length times maximum width (LW) for soybeans and comparing foliometer and LW for corn. There was close agreement between planimeter and foliometer measurements for soybeans (r = 0.99). The foliometer compared favorably with LW for corn (r = 0.96). Coefficients for converting LW measurements to leaf areas were determined for soybeans and three corn hybrids.

76:07B-020

SIMULATION MODEL FOR NUTRIENT UPTAKE FROM SOIL BY A GROWING PLANT ROOT SYSTEM,

Caassen, N. and Barber, S.A.
Agronomy, Fusagri, Cagua, Venezuela.
Agronomy Journal, Vol. 68, No. 6, p 961-964, November-December 1976. 1 fig, 1 tab, 13 ref.

Descriptors: Simulation analysis, Mathematical models, Model studies, Nutrients, Computer programs, Corn, Potassium, Diffusion.

Mathematical models of nutrient uptake by plants are useful for investigating the effect of various soil and plant factors on nutrient flux to plant roots. The objective of this research was to develop a model based on theoretical considerations of the processes of nutrient uptake by plant roots growing in soil and then to test the model experimentally. The soil and plant factors used in the model were to be measured independent of final nutrient uptake. The model for flux by mass flow and diffusion to the root was patterned after that of Nye and Marriott. The absorption kinetics of the root were assumed to follow Michaelis-Menten kinetics. The Nye-Marriott model gives the nutrient concentration at the root with time. From this accumulated uptake per sq cm of root surface with time was calculated. Rate of root growth was assumed exponential for the growth of the young plant. Upt[illegible] per sq cm of root with time was combined mathematically with rate of root growth to get total uptake with time by the plant. The present program assumes root hairs do not affect uptake and that roots do not compete for nutrients.

76:07B-021

A SYSTEM AND PROGRAM FOR MONITORING CO2 CONCENTRATION, GRADIENT, AND FLUX IN AN AGRICULTURAL REGION,

Rosenberg, N.J. and Verma, S.B.

Nebraska University, Institute of Agriculture and Natural Resources, Department
of Agricultural Engineering, Lincoln, Nebraska 68583
Agronomy Journal, Vol. 68, No. 2, - 414-418, March-April 1976. 3 fig, 6 ref.

Descriptors: Photosynthesis, Carbon dioxide, Nebraska, Sampling, Wind speed, Air temperature, Data collections.

Because of the changing global concentration of carbon dioxide and the possible effects of this change on photosynthetic activity worldwide, a program has been developed for monitoring atmospheric carbon dioxide concentration and gradients representative of a large agricultural region. The program is carried out at Mead, Nebraska. A meteorological tower is equipped with sampling intakes at various elevations up to 16 m, through which air is drawn to the laboratory for analysis with infra-red gas analyzers. An automatic calibration system has been developed to permit hourly checks of analyzer performance. Profiles of wind speed and air temperature are also measured. The equipment, the calibration techniques, and the errors associated with the measurements of CO2 concentration and gradients are described. Some initial observations of CO2 concentrations and fluxes are presented.

76:07B-022
THE CONCENTRATION OF DISSOLVED SOLIDS AND RIVER FLOW,
O'Connor, D.J.
Manhattan College, Department of Civil Engineering, Bronx, New York 10471
Water Resources Research, Vol. 12, No. 2, p 279-294, April 1976. 15 fig, 2 tab, 18 ref.

Descriptors: Dissolved solids, River flow, Rivers, Return flow.

A general expression for the spatial and temperal distribution of conservative dissolved solids in freshwater rivers which incorporates the contribution of both the groundwater and surface water components of river flow is presented. The first part of this paper deals with the steady state conditions. With certain simplifying assumptions the correlation between concentration of dissolved solids and flow is developed for both spatially uniform and nonuniform conditions. The analysis includes the effect of both geophysical discontinuities and point sources. Examples from a number of rivers throughout the country are presented to indicate the utility of the analysis. The second part addresses the temporal variation of the dissolved solids concentration for two time scales. One describes the annual variation in concentration due to the time variable components of the river flow, and the second the variation over a semimonthly period due to a time variable point input. Applications to a variety of river conditions are also presented for the time variable analysis.

76:07B-023
AN AUTOMATIC SYSTEM FOR MEASURING SALT CONCENTRATION PROFILES IN POROUS MEDIA,
Barnes, P.L., Smajstrla, A., and Reddell, D.L.
Texas A and M University, Department of Agricultural Engineering, College Station, Texas
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, 14 p, December 14-17, 1976, Chicago, Illinois. 5 fig, 2 equ, 9 ref.

Descriptors: Salinity, Soil salinity, Saline soils.

The construction of a low-cost salinity sensor is described which is easily constructed. Also, an electronic circuit which automatically reads and records field and laboratory data from multiple salinity sensors is presented. With this system, salinity data can be collected from several hundred sensors in a short time period. This information can be used to predict and manage real land potential pollution movements in soils.

76:07B-024
POLLUTION PROBABILITY ESTIMATED BY SMALL STORM FREQUENCY,
Lewis, R.B., Huaser, V.L., Menzel, R.G., and Ross, J.D.
Texas Tech University, Department of Agricultural Engineering, Lubbock, Texas.

Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, 23 p, December 14-17, 1976, Chicago, Illinois. 10 fig, 4 tab, 10 ref.

Descriptors: Surface runoff, Runoff, Return flow, Water quality, Water quality management, Hydrologic data, Hydrologic aspects, Nebraska, Corn, Crop production.

The concentration of chemicals in surface runoff water is often an important consideration. Water soluble chemicals which are applied to the surface of plants or soil may appear in the highest concentration in runoff water from small storms. Because of this, some aspects of water quality management require quite different hydrologic information than has been required to solve problems considered in the past. This study of small storms in the central Great Plains near Hastings, Nebraska, revealed much about small storms and their relation to water quality. Contour cultivation of corn substantially decreased the number of runoff events resulting from small storms, and thus substantially decreased the likelihood of pollution from surface applied chemicals. Our finding agrees with past concepts, like the large decrease in annual runoff from corn which results from contour tillage. However, contour tillage of small grains (wheat and oats) did not cause a corresponding decrease in the number of runoff events from small storms. This finding conflicts with annual runoff data that shows a decrease in runoff from contour tillage of small grains.

76:07B-025
A MODEL TO PREDICT TOTAL ENERGY REQUIREMENTS AND ECONOMIC COSTS OF IRRIGATION SYSTEMS,
Chen, K-K,m Wensink, R.B., and Wolfe, J.W.
Oregon State University, Department of Agricultural Engineering, Corvallis, Oregon.
Presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, 23 p, December 14-17, 1976, Chicago, Illinois. 11 fig, 4 tab, 4 ref.

Descriptors: Computer models, Model studies, Simulation analysis, Economics, Irrigation, Irrigation systems, Sprinkler irrigation, Surface irrigation, Energy.

A computer model has been developed to simulate total fossil energy requirements and economic costs for hand move, side roll, solid set, permanent, center pivot, drip and surface systems. In addition to evaluating a specific design, the analyst can direct the program to search for minimum economic and/or minimum energy designs for a specific system. The moedl was used to determine the effects of static pumping lifts on minimum energy and minimum economic designs. The fossil energy utilization hierarchy was shown to be a function of pumping lifts, with the surface system the most efficient at zero-foot lift and the least efficient at pumping lifts above a few hundred feet. The economic hierarchy was also a function of pumping lifts. However, drip produced the lowest annual per acre cost at all pumping depths. The difference in annual fossil energy requirements and economic cost between energy and economic designs were relatively small. However, initial investment costs of the energy designs averaged 11.6 percent larger than the economic designs. Although economic designs annually consumed an average of 76 kilowatt-hours more electric energy than energy designs, energy designs annually cost 7.24 dollars per acre more.

76:07B-026
SOIL SALINITY TESTING IN THE FIELD,
Irrigation Journal, Vol. 26, No. 1, p 14-15, January-February 1976. 3 fig.

Descriptors: Salinity, Saline soil, Electrical conductance, Electrodes.

One of the more important chores of an agricultural water manager treating saline soils is getting accurate information of the concentration and extent of soluble salts in such soils. Eyeballing crops and soils in such areas is not enough since salinity may reduce crop yields by as much as 25 percent without visible symptoms. U.S. Department of Agriculture at the Agricultural Research Service's Salinity Laboratory in Riverside, California, has developed two devices that could make life easier for those charged with keeping salinity down to manageable levels. The devices may one day play a part in reducing or preventing farm income losses from salinity as well as aid in preventing environmental pollution.

76:07B-027
INFORMATION STORAGE AND RETRIEVAL FOR EVALUATION OF IRRIGATION POTENTIAL,
Rochester, E.W., McGuire, J.A., and Stallings, J.L.
Auburn University, Agricultural Experiment Station, Auburn, Alabama 36830
Paper No. 76-2035, Presented at the Annual Meeting of the American Society of Civil Engineers, June 27-30, 1976, Lincoln, Nebraska, 3 fig, 5 ref.

Descriptors: Computers, Information retrieval, Alabama, Crop production, Soils, Climate, Irrigation.

A computerized information storage and retrieval system is being developed in Alabama. The system called ARIS, is based on commercially available software and makes available numerical data about the resources of the State. Included in the utilization of ARIS is the evaluation of irrigation potential. Data describing soils, climate, water and crops are being encoded for this evaluation.

76:07B-028
MAP OF SALTY SOILS OF AFRICA,
Aubert, G.
Office de la Recherche Scientifique et Technique Outre-Mer, Bondy, France.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 598-604. 22 ref.

Descriptors: Salinity, Saline soils, Salts, Africa, Mapping, Maps.

This map is presented as part of the ISSS-UNESCO Project, in cooperation with the desertification map project of FAO and UNEP. It has been compiled with the assistance of S.A. Radwanski and G. Murdoch of the Land Resources Division of the United Kingdom, numerous directors of soils programs in African countries, J. Riquier of FAO, and pedologists of ORSTOM.

76:07B-029
BASIC PRINCIPLES FOR PROGNOSIS AND MONITORING OF SALINITY AND SODICITY,
Massoud, F.I.
Food and Agriculture Organization, Soil Resources Development and Conservation Service, Land and Water Development Division, Rome.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 432-454. 67 ref.

Descriptors: Salinity, Sodium, Saline soils, Sampling, Salt balance, Salts, Drainage, Evapotranspiration, Irrigation water, Groundwater.

The development of a standardized methodology for prognosis and monitoring of salinity and sodicity for application throughout the world may not be easily achieved or appropriate practically where conditions vary from one location to another as is the case in salt affected soils. Moreover, there is usually an element of risk in attempting to transfer the procedures and to over-generalize the use of an established standard methodology without giving enough consideration to local changes or needs. The common tendency to adopt rather than to adapt a methodology quite often gives misleading results and it would be more fruitful and, in this case essential, to go through the rigors of applying the principles. Therefore, knowledge of the basic principles discussed in this paper is an indispensible requirement for the development of local procedures or the adoption of an established methodology.

76:07B-030
SALINITY SURVEY IN ISRAEL,
Boaz, M., Husenberg, I., and Posin, Y.
Irrigation and Soil Field Service, Ministry of Agriculture, Tel-Aviv, Israel.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 388-399. 3 fig, 4 tab.

Descriptors: Salinity, Surface, Electrical conductance, Saline water, Chlorides, Dissolved solids, Orchards, Crop production, Crop response.

The Salinity Survey was initiated in the Spring of 1963, a year before the operation of the National Water Carrier, which conducts water from Lake Tiberias in the North, to the Southern parts of the Country. The electrical conductivity (EC) of the lake water at that time was 1.5 millimhos/cm, with a chloride content of about 350 ppm and about 1000 ppm total dissolved salts (TDS). The salinity of the lake water at the present time is considerably lower: EC approximately 1.2 mmhos/cm; Cl approximately 250 ppm; TDS approximately 850 ppm. It was feared that the water would be too saline for the irrigation of sensitive crops like citrus, which is the country's main agricultural export.

SECTION XXXVII

RESOURCES DATA

EVALUATION, PROCESSING AND PUBLICATION (GROUP 07C)

76:07C-001
A SIMPLE COMPUTER PROGRAM FOR THE DETERMINATION OF AQUIFER CHARACTERISTICS FROM PUMP TEST DATA,
Holzschuh, J.C., III.
Southwest Florida Water Management District, Brooksville, Florida.
Ground Water, Vol. 14, No. 5, p 283-285, September-October 1976. 3 fig, 1 tab, 2 ref.

Descriptors: *Computer programs, *Data processing, *Aquifer characteristics, *Pump testing, Estimating, Analytical techniques, Graphical methods, Graphical analysis, Leakage, Transmissivity, Storage coefficient, Hydraulic conductivity.

A computer program, based on the Hantush inflection method and designed for "desk top" computers was presented. The method assumed a leaky, isotropic, homogeneous aquifer of infinite areal extent. The language employed was BASIC, and interactive language used on the Wang Model 2200 programmable calculator. The program can be easily adapted to FORTRAN IV for use on larger machines.

76:07C-002
CONVERSION OF IRREGULAR FINITE ELEMENT GRID DATA TO REGULAR GRID FOR THREE-DIMENSIONAL COMPUTER PLOTTING,
Gupta, S.K., Morrissey, M.W., Lonczak, J., and Tanji, K.K.
California University, Department of Land, Air, and Water Resources, Water Science and Engineering Section, Davis, California 95616
Water Resources Research, Vol. 12, No. 4, p 809-811, August 1976. 3 fig, 4 ref.

Descriptors: Finite element analysis, Computers, Computer models, Computer programs.

Three-dimensional plotting provides a useful means for the illustration and interpretation of results from finite element simulation. The computer graphic packages usually available at computer center, however, require data on regular grids and thus are not adaptable to isoparametric finite elements, which are combinations of various shapes and sizes of trapezoids. By using the basic functions, a method is presented for the estimation of regular grid values from irregular gridded data for plotting purposes.

76:07C-003
SALINE WATER CLASSIFICATION IN IRAN BY RATIONAL METHODS,
Massoumi, A.M.
Tehran University, College of Agriculture, Department of Soil Science, Karadj, Iran.
Proceedings of the International Salinity Conference, Texas Tech University, Lubbock, Texas, August 16-20, 1976, p 455-465. 4 fig, 3 tab, 4 ref.

Descriptors: Saline water, Salinity, Irrigation efficiency, Irrigation, Irrigation water.

The classification of saline water is very important for irrigation projects in Iran. The application of U.S.S.L. method has not given a good result in this country. Therefore, it was decided to examine the rational method which is based on plant resistance against the salinity, the texture of soils, and irrigation efficiency. For a given plant, growth in a given soil, the quality of irrigation water depends only on the efficiency of irrigation.

76:07C-004
FIELD TESTING OF A NEW SYSTEM FOR QUALIFYING IRRIGATION WATER,
Sentis, I.P., and Dappo, F.

Instituto de Edafologia, Universidad Central de Venezuela, Maracay, Venezuela.
Proceedings of the International Salinity Conference, Texas Tech University,
Lubbock, Texas, August 16-20, 1976, p 376-387. 1 fig, 5 tab, 14 ref.

Descriptors: Irrigation water, Salinity, Salts, Saline soil, Salt balance, Leaching, Calcium, Magnesium, Drainage, Crop production, Sodium.

A new system for evaluating irrigation waters in relation to the potential problems of salinity and sodicity is tested under five different situations of salt affected soils in Venezuela. The system is based on an independent balance of the different ions in soil solution in relation to the effective leaching and limiting solubilities of Ca sulfates and Ca plus Mg carbonates. Qualification is based not only on the concentration and composition of salts in irrigation water but on the drainage conditions of the soil profile and on the crop tolerance.

SECTION XXXVIII

ENGINEERING WORKS

HYDRAULICS (GROUP 08B)

76:08B-001
SEGMENTAL ORIFICES WITH SHUNT METERS TO TOTALIZE PIPELINE FLOW,
Kruse, E.G., and Young, D.A.
Agricultural Research Service, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 5, p 871-875, September-October 1976. 7 fig, 2 tab, 3 ref.

Descriptors: *Pipe flow, *Flow rates, *Measurement, *Irrigation engineering, Instrumentation, Calibrations, Laboratory tests, Orifices, Discharge (Water), Discharge measurement, Flowmeters, *Flow measurement, On-site tests.

Four segmental orifice plates were constructed and evaluated for use with domestic water meters in shunt lines for totalizing irrigation flow. Total pipe flow was related to shunt-line flow in the laboratory; then two field installations in self-propelled, center-pivot sprinklers were evaluated for two seasons. After two years of field evaluations, an accuracy of plus or minus 8% of true flow was noted, which is suitable for use in determining groundwater draft by irrigation wells.

76:08B-002
A THEORY OF FLOW RESISTANCE FOR VEGETATED CHANNELS,
Thompson, G.T., and Roberson, J.A.
Washington State University, Department of Civil and Environmental Engineering, Pullman, Washington.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 2, p 288-293, March-April 1976. 5 fig, 12 ref.
(See 76:04A-003)

76:08B-003
BAYESIAN APPROACH TO TILE DRAIN DESIGN,
Musy, A., and Duckstein, L.
Ecole Polytechnique Federale de Lausanne, Department of Agriculture, Switzerland.
Journal of the American Society of Civil Engineers, Vol. 102, No. IR3, p 317-334, September 1976. 7 fig, 3 tab, 30 ref.

Descriptors: *Tile drainage, *Land reclamation, *Decision making, Agricultural engineering, Design, Water management (Applied), Hydrology, Equations, Economics, Costs, Systems analysis, Methodology, Crops, Evaluation, Optimization, *Tile drains, Risks.

Economic and sociopolitical aspects of land reclamation in areas that necessitate drainage are combined with technical problems to yield a set of possible decisions, among which an optimum design is chosen. The loss or objective function is the sum of the expected damage caused by the submersion of given crops resulting from extreme rainfall events, and the initial cost of the reclamation. When the parameter uncertainty in the probability distribution function of extreme events is taken into account in the loss function, a Bayes risk function is obtained. The Bayes decision theoretic (BDT) approach consists of seeking a decision that minimizes the Bayes risk function. The BDT also evaluates the decision taken and compares the expected cost of delaying the construction to the worth of additional information resulting from such a delay. The practical example of an intensive agricultural system with different types of soils and crops illustrates the methodology. Crop loss functions and probability distributions of events are assumed on the basis of empirical observations.

76:08B-004
TEMPERATURE EFFECTS ON EMITTER DISCHARGE RATES,
Parchomchuk, P.
Agriculture Canada, Research Station, Summerland, British Columbia, Canada.
Transactions of the American Society of Agricultural Engineers, Soil and Water,
p 690-692, Special Edition 1976. 5 fig, 1 tab, 4 ref.

Descriptors: *Temperature, *Water temperature, *Viscosity, Flow rates, Uniformity coefficient, Hydraulics, Irrigation, Irrigation systems.

One of the major requirements of trickle irrigation is precise control of water application rate. To attain optimum control, all emitters must deliver water at equal rates and rates should not change with time or environmental factors. There is general agreement that discharge rates should not vary more than ±10 percent for uniform water application. Variations in emitter manufacture or operating pressure are cited as the major sources of emitter discharge variation (Keller and Karmeli, 1974). However, an additional factor which could result in large emitter discharge variations is water temperature variation. Viscosity changes, due to changing water temperatures, cause emitter discharge variations greater than the maximum ±10 percent limit if flow through the emitter is laminar. Turbulent flow emitters, on the other hand, are not affected by viscosity changes. Water temperature variations can occur in a number of ways. Temperature variation occurs over a period of time with day-night, day to day and seasonal weather changes and from end to end of lateral lines due to solar heating of black plastic pipe. Water temperatures in lateral lines as high as 77°C (170°F) have been reported. This study investigates the effect of water temperature variation upon discharge rates of several emitter types. Water temperature variation in lateral lines was measured to determine expected discharge variations.

76:08B-005
TRANSVERSE MIXING IN NATURAL CHANNELS,
Yotsukura, N. and Sayre, W.W.
United States Geological Survey, National Center 430, Reston, Virginia 22092
Water Resources Research, Vol. 12, No. 4, p 695-704, August 1976. 8 fig, 25 ref.

Descriptors: Mathematical models, Model studies, Channel flow, Channels, Mixing, Simulation analysis.

A mathematical model is presented for predicting the steady state two-dimensional distribution of solute concentration in a meandering nonuniform natural channel. Two features of the convection-diffusion (mixing) equation derived herein are that it employs the transverse cumulative discharge as an independent variable replacing the transverse distance and that it is developed in an orthogonal curvilinear (natural) coordinate system which follows the general direction of the channel flow. With the help of the continuity equation of water the transverse convection term which cannot be neglected in a natural channel is eliminated from the mixing equation by a transformation wherein cumulative discharge replaces transverse distance. Introduction of scalar diffusivity coefficients into the mixing equation is found to be more justifiable in the natural coordinate system than in a rectangular Cartesian coordinate system. The transformed mixing equation unifies and generalizes essential concepts of several existing models which have been used successfully for simulating steady state transverse mixing in irregular natural channels. Solution methods, both analytical and numerical, and parameter estimation methods are presented, after which some results of simulation are compared with observed data.

76:08B-006
HYDRAULIC CHARACTERISTICS OF IRRIGATION FURROWS,
Ramsey, M.K. and Fangmeier, D.D.
Arizona University, Department of Soils, Water, and Engineering, Tucson, Arizona.
Paper No. 76-2046, Presented at the Annual Meeting of the American Society of
Civil Engineers, June 27-30, 1976, Lincoln, Nebraska, 17 p, 4 fig, 5 ref.

Descriptors: Infiltration, Furrow irrigation, Furrows, Furrow systems, Irrigation systems, Irrigation effects, Hydraulics.

Seven irrigations were conducted on a precision field furrow. Inflow, outflow, water surface elevations, soil surface elevations, and furrow geometry were measured. Methods of determination and comparisons of infiltration functions, effect of flow depth on intake, and flow resistance parameters are presented.

76:08B-007
ENERGY ECONOMICS IN PIPE AND SYSTEM SELECTION,
Keller, J.
Utah State University, Department of Agricultural and Irrigation Engineering, Logan, Utah.
1976 Annual Technical Conference Proceedings, Sprinkler Irrigation Association, Technology for a Changing World, February 22-24, 1976, Kansas City, Missouri, p 134-145, 4 fig, 2 tab, 6 ref.

Descriptors: Energy, Irrigation design, Hydraulics, Irrigation systems, Pipe flow, Pipes, Irrigation efficiency, Hydraulic design.

A rational means for using economic factors as the basis for selection of pipe and irrigation system components is presented. A graphical method developed by Keller (3) is also presented which can be used to speed the economic sizing of mainline pipes.

76:08B-008
VENTURI FLUMES FOR CIRCULAR CHANNELS,
Diskin, M.H.
Arizona University, Department of Hydrology and Water Resources, Tucson, Arizona
Journal of the Irrigation and Drainage Division, Vol. 102, No. IR3, p 383-387, September 1976. 4 fig, 1 tab, 6 ref.

Descriptors: Flumes, Flow measure, Flow rates, Venturi flumes, Open channels.

The principle of operation and the advantages of Venturi flumes for open-channel flow measurements are well known and amply documented in technical literature dealing with flow measuring methods. The main advantages are the ability to adapt the shape of the flume to the shape of the channel and to the range of flows expected, the possibility of predicting the coefficients of discharge either by theoretical considerations or from results of calibration tests, and finally the relatively small head losses possible with Venturi flumes as evident by the high values of allowable submergence. The purpose of this paper is to present some experimental results for Venturi flumes. While these designs may be used also as Venturimeters for full pipe flow, the results given herein refer only to open-channel flow at a mild slope. The results are not applicable to steep channels where the flow is supercritical and a jump forms a short distance upstream of the flume. Information about the limiting submergence of the flumes tested is also presented.

SECTION XXXIX

ENGINEERING WORKS

MATERIALS (GROUP 08G)

76:08G-001
SHUNT LINE METERING SYSTEM FOR IRRIGATION WELLS,
Hill, W.C., and Ruff, J.F.
Colorado State University, Department of Civil Engineering, Fort Collins, Colorado.
Transactions of the American Society of Agricultural Engineers, Vol. 19, No. 3,
p 494-500, May-June 1976. 15 fig, 2 tab, 5 ref.

Descriptors: *Flow measurement, *Wells, *Irrigation wells, *Orifices, Calibrations, Laboratory tests, Equations, Mathematical studies, Instrumentation, Measurement, Pipes.

The testing and development of a shunt line metering system with segmental orifice were described. This type of metering system provides a low cost means of cumulatively measuring the volume of water discharged from irrigation wells. The flow through the shunt line, which was measured by a small household type water meter, was related to the flow through the main irrigation pipe by a flow coefficient which was experimentally determined for a 15.41 cm (6 in) pipe. This flow coefficient is a function of the degree of orifice contraction. It was pointed out that the field calibration of the meter was not necessary. The cost of the metering system can be less than $100 and the accuracy was shown to be within + or - 5 percent.

76:08G-002
FIELD EVALUATION OF 102-MM (4-INCH) CORRUGATED POLYTHYLENE TUBING,
McCandless, D.E., Jr.
United States Department of Agriculture, Soil Conservation Service, Department of Water Management Engineering, Broomall, Pennsylvania.
Transactions of the American Society of Agricultural Engineers, Soil and Water,
p 514-516, Special Edition 1976. 7 tab, 3 ref.

Descriptors: Drainage, Drainage engineering, Drainage practices.

A field evaluation of the physical condition of installed 102 mm (4 in.) corrugated polyethylene tubing was made in four states in the northeast by the United State Department of Agriculture Soil Conservation Service. Elongation and deflection data were summarized on tubing from 54 sites. Deflections of 13 to 25 percent were typical, however, seven sites had deflections greater than 35 percent. The tubing was elongated 4.2 percent on the average when installed with a wheel trenching machine.

76:08G-003
COMPLEXES AFFECTING THE SOLUBILITY OF CALCIUM CARBONATE IN WATER - PHASE II,
Larson, T.E., Sollo, F.W., Jr., and McGuirk, F.F.
Illinois State Water Survey, Urbana, Illinois.
Illinois Water Resources Center, Urbana, Research Report No. 108, February 1976.
57 p, 17 tab, 39 ref. OWRT B-082OILL(1). 14-31-0001-4078.

Descriptors: *Hardness (Water), *Scaling, *Corrosion, *Calcium carbonate, Magnesium, Sodium, Potable water, Water quality, *Solubility, *Hydrogen ion concentration, Volumetric analysis, Water supply.

Water utilities have a tremendous investment in the miles of pipe, valves, and other appurtenances in water distribution systems. Failure to protect these systems against corrosion and excessive scale formation could necessitate replacement of the distribution systems at an estimated cost of $25 billion. Calculation of the true equilibrium or saturation pH, pHs, for calcium carbonate and adjustment of the water to that pH is essential to supply water of high quality and to avoid corrosion and scale formation in these water distribution systems. In some cases the actual pH must be from 0.6 to 1.0 unit above pHs, as determined from the calcium and alkalinity analyses. Certain complexes may be responsible in part for this fact. The objective of this study was to evaluate the dissociation constants of the complexes so that the optimum pH can be more accurately calculated. A titration method was used to measure the effects of complex formation on the pH of reaction mixtures and appropriate computer programs were developed to calculate the dissociation constants. Experimental procedures and results from the determination of dissociation constants for complexes of magnesium, calcium and sodium with carbonate, bicarbonate, hydroxide, and sulfate and a method to utilize these constants in calculating pHs in public water supplies are discussed.

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76:03C-010
76:03C-012
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76:03C-017
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76:05A-013
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76:02F-003
76:02F-006
76:02F-024
76:02F-034
76:02G-050
76:02G-054
76:02G-128
76:02J-006
76:02K-012
76:03C-011
76:03C-012
76:03C-013
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76:03F-135
76:04D-006
76:05A-002
76:05A-005
76:05A-007
76:05A-009
76:05B-001
76:05B-002
76:05B-004
76:05B-007
76:05B-011
76:05B-016
76:05B-019
76:05B-021
76:05B-029
76:05B-033
76:05B-040
76:05B-041
76:05B-042
76:05B-043
76:05B-049
76:05B-051
76:05B-052
76:05B-056
76:05C-001
76:05C-002
76:05D-003
76:05G-001
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76:05G-015
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76:05G-017
76:05G-019
76:05G-022
76:06A-006
76:06A-011
76:06E-001
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76:02B-003
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76:03B-001
76:03E-001
76:03F-028
76:03F-030
76:04A-004
76:04B-009
76:05B-043
76:05B-051
76:05C-001
76:05G-012
76:05G-015
76:05G-016
76:06A-001
76:06A-002
76:06A-004
76:06A-005
76:06A-007
76:06A-011
76:06E-002
76:06F-001

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76:02J-008
76:02J-016
76:03C-001
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76:04C-001
76:04D-003
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76:02E-013
76:02E-014
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76:02A-005
76:02A-006
76:02E-001
76:02E-006
76:02E-007
76:02E-009
76:92F-028
76:02G-013
76:02J-010
76:03B-002
76:03B-004
76:04A-006
76:04D-001
76:04D-003
76:05B-002
76:05B-009
76:05B-011
76:05B-018
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76:02D-013
76:03A-001
76:03E-001
76:03F-029
76:04C-001
76:05A-013
76:06A-002
76:06A-003
76:06A-006
76:06C-002
76:06D-001
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76:06A-006
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76:02F-016
76:02F-019
76:02F-022
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